296 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

INSIDE

GIRAFFES
WHY DO THEY HAVE SUCH LONG NECKS?

SCIENCE ENVIRONMENT SPACE

WORLD'S FASTEST TRAINS
Travel at 300mph on board the Maglev

LIFE IN SPACE
Astronauts answer your questions

CAN THE BRAIN HEAL ITSELF?

CAN WE READ MINDS?

WHY IS SLEEP SO IMPORTANT?

WHY DO TEENAGERS WAKE UP LATE?

YOUR AMAZING BRAIN

DISCOVER THE SECRETS OF THE BODY'S MOST COMPLEX ORGAN

BUBBLES
Discover the science behind beautiful floating spheres

+ LEARN ABOUT

- SMART HOMES
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Xduro AMT pro 27.5

27.5", All Mountain, 150mm travel, 4-Link System • Bosch Performance 36 Volt, 250 Watt Motor, 60Nm Torque
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ISSUE 64

WELCOME

The magazine that feeds minds!

Page 62
You can read about the incredible migration of the wildebeest and many other animals

Explaining how the human brain works could be our biggest challenge yet. The wrinkled heap inside your head controls every thought, breath and movement you'll ever make. It's always active and generates enough energy to power a light bulb. The wiring, however, is much more complex than any electrical appliance.

Ambitious scientists are attempting to rebuild a digital brain from the bottom up, but it's an immense task. The average human command centre contains enough axons to wrap around the Earth four times over. In this issue, we explain some of the most groundbreaking findings, from mind-reading computers to the ability to link human brains together.

We also explore the world's fastest trains that are cutting down commutes quicker than you can say "tickets, please?" There are also interviews with real-life astronauts, revealing what it's like to live, eat and socialise in space, and we'll have you back home in time for tea inside the smartest homes on Earth.

Enjoy!

Jodie

Jodie Tyley
Deputy Editor

Meet the team...

Andy
Designer
This is my first issue on **How It Works**, but after going through the Brain Dump I already feel like I could take on any pub quiz.

Erlingur
Production Editor
The *Minority Report*-like smart homes of the future are quickly becoming the homes of today – my robot butler shares my enthusiasm.

Jamie
Staff Writer
As a lifelong Thomas the Tank Engine fan, the high-speed trains feature showed me how much train travel has evolved.

Jackie
Research Editor
I enjoyed learning about the animals that undertake epic journeys across the world in this month's migration feature.

Hannah
Assistant Designer
If you have ever wondered what a bee looks like when it's completely covered in pollen, you can turn to page 20 to find out.

Jack
Staff Writer
Almost everyone has dreamt of being able to go to space so being able to speak to four NASA astronauts was pretty cool!

What's in store

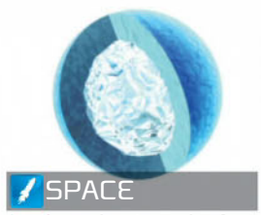
Check out just a small selection of the questions answered in this issue of How It Works

SCIENCE
What are bubbles and how do they float? **Page 23**

ENVIRONMENT
Why do giraffes have nature's longest necks? **Page 70**

TRANSPORT
How do planes manage to refuel in mid-air? **Page 46**

TECHNOLOGY
How does self-cleaning glass get rid of dirt? **Page 54**



SPACE
Are there planets made of diamonds in space? **Page 35**

HISTORY
What's behind Cardiff Castle's fairy-tale design? **Page 74**

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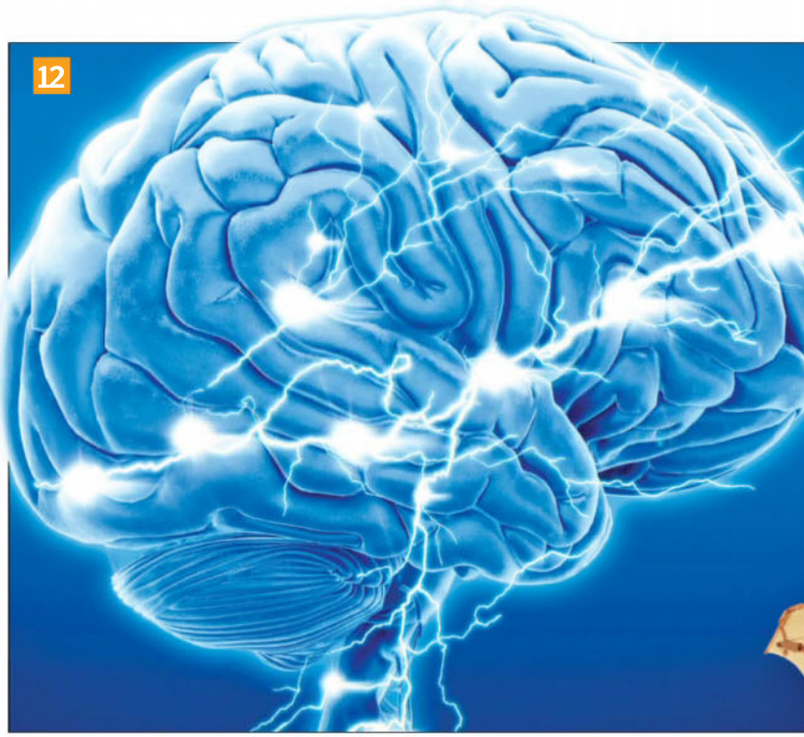
Understanding and revealing the mysteries of the body's most complex organ



SCIENCE

SPACE

TRANSPORT

TECHNOLOGY

ENVIRONMENT

HISTORY

Meet the experts...

Laura Mears
Your amazing brain
This month's cover feature was beamed from Laura's brain – and considerable research – straight to yours. Discover the fascinating research that indicates mind-reading is indeed possible on page 12!

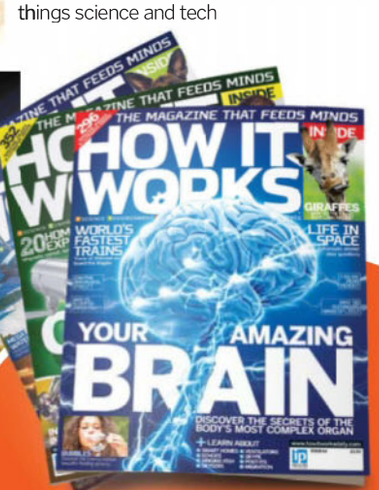
Hayley Paterek
Giraffe anatomy
Flip to the Environment section to read about the fish that serenade their underwater lovers, the life cycle of a stag beetle and the answer to why giraffes have such long necks.

Lee Sibley
Smart rear-view mirror
Car expert Lee delves into new tech from Nissan that solves the problem of blind spots. Find out how their new rear-view mirror uses cameras to see all around your vehicle on page 44.

Steve Wright
Da Vinci's glider
Radio presenter turned **How It Works** writer (kidding) explains how inventor Leonardo da Vinci created the manned glider. It didn't quite get off the ground, it was a landmark step in aviation.

Gemma Lavender
Diamond planets
Inside the Space section, you'll discover real-life diamond planets, mysterious magnetic stars and volcanoes on Venus, explained by our resident expert Gemma.

REGULARS



HMS Queen Elizabeth

All aboard the warship that's taller than Niagara Falls

This is the HMS Queen Elizabeth, the largest surface warship ever built for the Royal Navy. Officially named in July 2014, the mammoth vessel is due to enter service in 2020. It signals a new era for the Navy, replacing the older Invincible class of aircraft carrier. Each ship can carry up to 40 aircraft and is five metres (16.4 feet) taller from top to bottom than the Niagara Falls! The ship is a gigantic structure but it is not on its own, as it will ultimately be joined by the second and final vessel in the Queen Elizabeth class of carrier, the HMS Prince of Wales.

The statistics...

HMS Queen Elizabeth

Length: 280m (919ft)

Width: 70m (230ft)

Height: 56m (184ft)

Range: 18,520km (11,508mi)

Power: 72MW (that's a whopping 96,554 horsepower!)

An electrician inspects the interior of the ship. An onboard water plant will produce 500 tonnes of fresh water every day

Have an ice stay

Check yourself in to the world's first floating snowflake hotel

Talk about a room with a view – this new floating ice hotel offers the best spot to observe the meteorological phenomena aurora borealis. Devised by company Dutch Docklands, the five-star Krystall Hotel will only be accessible by boat and will blend in naturally with the fjords in winter. It will be supplied with 86 rooms, conference facilities and a spa. The project is designed to be a 'scarless development', which will not leave any sort of physical footprint on the environment. If successful, similar constructions may pop up in other resorts and areas of natural beauty such as the Maldives and other remote islands. The building is due to open around Christmas 2016 and will most likely be located near the city of Tromsø in Northern Norway.

Construction on the hotel will begin in mid-2015 and will cost ca £60 million ($100 million)

Unusual hotels

The award for quirkiest hotel could well go to the Dog Bark Park Inn in Idaho, USA. You are quite literally in the doghouse in 'the largest beagle in the world', which is over nine metres (29.5 feet) high. The inn, which can be described as a Trojan dog, is a bed and breakfast containing a comfy queen-sized bed so you won't have a (ahem) ruff night.

WWI replica biplane takes to the skies

The Great War is commemorated by a replica biplane flight

The First World War marked the birth of aerial warfare as dogfights raged all across Europe. As a mark of respect to the brave men of the Royal Flying Corps, pilot Matthew Boddington and navigator Stephen Slater flew a replica BE-2 biplane in a remembrance service on 13 August 2014. Around 3,500 BE-2 planes were built and they were initially used solely as a reconnaissance aircraft, but soon developed into a light bomber and night fighter. The service was in memory of the British Expeditionary Force's arrival in Arras, France, 100 years ago to the day.

AMAZING VIDEO!

Watch a BE-2 biplane in flight

www.howitworksdaily.com

SCAN THE QR CODE FOR A QUICK LINK

Find out more about planet Earth

Learn new things every month with How It Works Illustrated

The second issue of **How It Works Illustrated** is now on sale! **How It Works Illustrated** is a travel-sized magazine packed full of vivid, colourful illustrations and interesting articles for everyone to enjoy. This month's issue focuses on Earth and all its natural wonders, answering questions like can you start an avalanche by shouting? And what's the world's longest burning fire? This edition will also contain an incredible ten-page journey inside the Earth!

WWW.HOWITWORKSDAILY.COM

On the edge of the Solar System

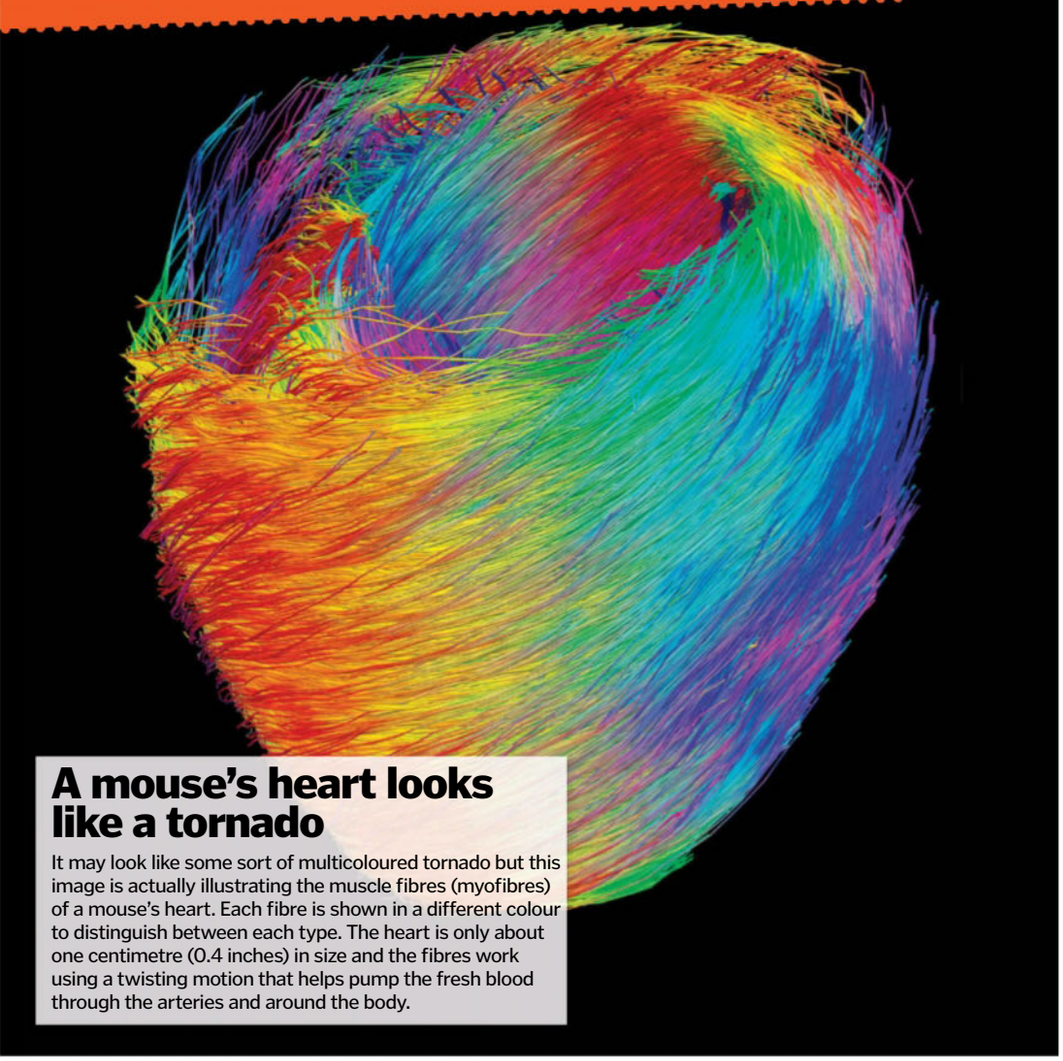
NASA's New Horizons probe is now only a year away from Pluto

Launched in 2006, the New Horizons spacecraft is on an epic journey to the outer reaches of the Solar System. It will study the distant Kuiper Belt of asteroids and is scheduled to reach Pluto just under one year from now. It is currently located between the dwarf planet and the outermost gas giant Neptune. The craft has already crossed a staggering 4.4 billion kilometres (2.7 billion miles) of space and has undertaken navigation exercises around Jupiter and the Galilean moons.

The New Horizons spacecraft has studied Jupiter and several moons on its long journey

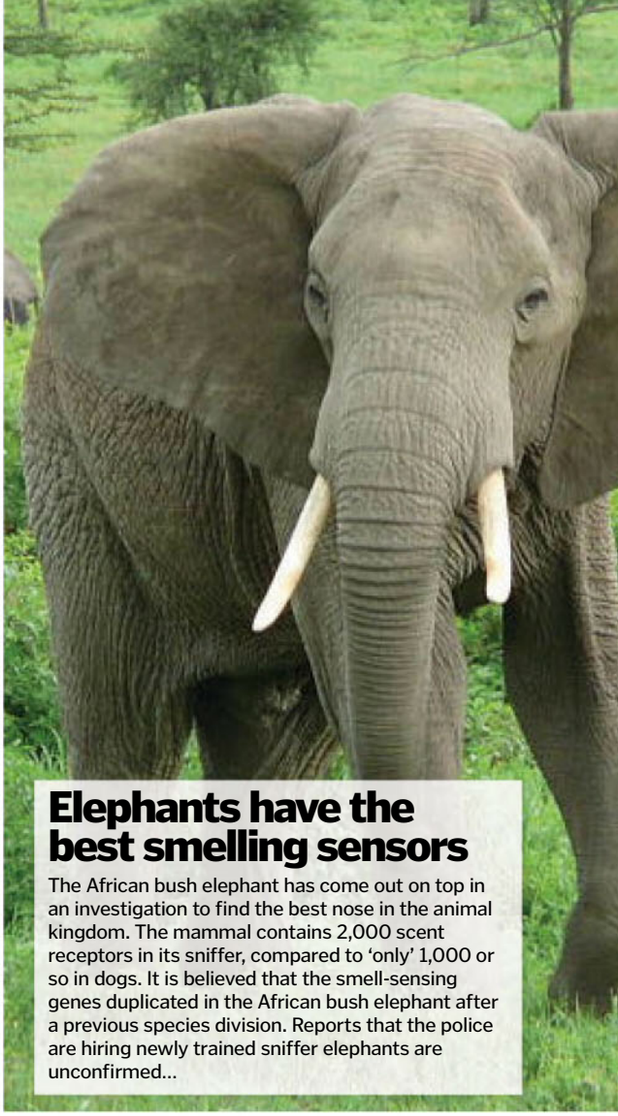
GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH



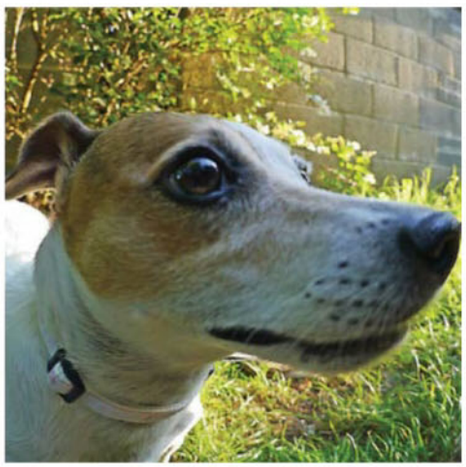
A mouse's heart looks like a tornado

It may look like some sort of multicoloured tornado but this image is actually illustrating the muscle fibres (myofibres) of a mouse's heart. Each fibre is shown in a different colour to distinguish between each type. The heart is only about one centimetre (0.4 inches) in size and the fibres work using a twisting motion that helps pump the fresh blood through the arteries and around the body.



Elephants have the best smelling sensors

The African bush elephant has come out on top in an investigation to find the best nose in the animal kingdom. The mammal contains 2,000 scent receptors in its sniffer, compared to 'only' 1,000 or so in dogs. It is believed that the smell-sensing genes duplicated in the African bush elephant after a previous species division. Reports that the police are hiring newly trained sniffer elephants are unconfirmed...



Face recognition can find your lost dog

The days of putting up posters of your lost pooch are over. Scientists at the University of Utah have made an app that uses facial recognition to help others find your missing pet by uploading a picture to www.FindingRover.com.

Lower testosterone is the key to civilisation

Evidence has shown the human race only began to boom about 50,000 years ago after a significant lowering of testosterone in the human body. The levels of testosterone were measured by analysing the differences in facial shape on many ancient skulls. By curbing their aggression, the brain developed to appreciate art and technology so society and civilisation could begin to flourish.

There's a new disease-detecting app

It seems there's an app for everything these days. Now your smartphone can even analyse your very own blood cells! *Athelas* works by uploading a picture of your blood to its server where in-house experts will study the sample. Using a predictive cell-counting method, the app's creators have claimed that it can help detect malaria and some types of cancer.

Saturated fats aren't all bad

Saturated fats get a pretty bad rap most of the time. However, recent research has found that saturated fats in dairy products aren't as harmful as previously thought and could in fact prevent the onset of type-2 diabetes. This is because they have an odd number of carbon atoms while saturated fats from red meat and fried food contain the devilish even number.

An endangered beetle is rediscovered

A rare insect known as the iridescent tansy beetle has been spotted in Cambridgeshire, England, for the first time since 1973. The critter was thought to only exist in Yorkshire but the Woodwalton Fen National Nature Reserve could now be another potential home for the creepy crawler.

Worms stabilised Earth's oxygen

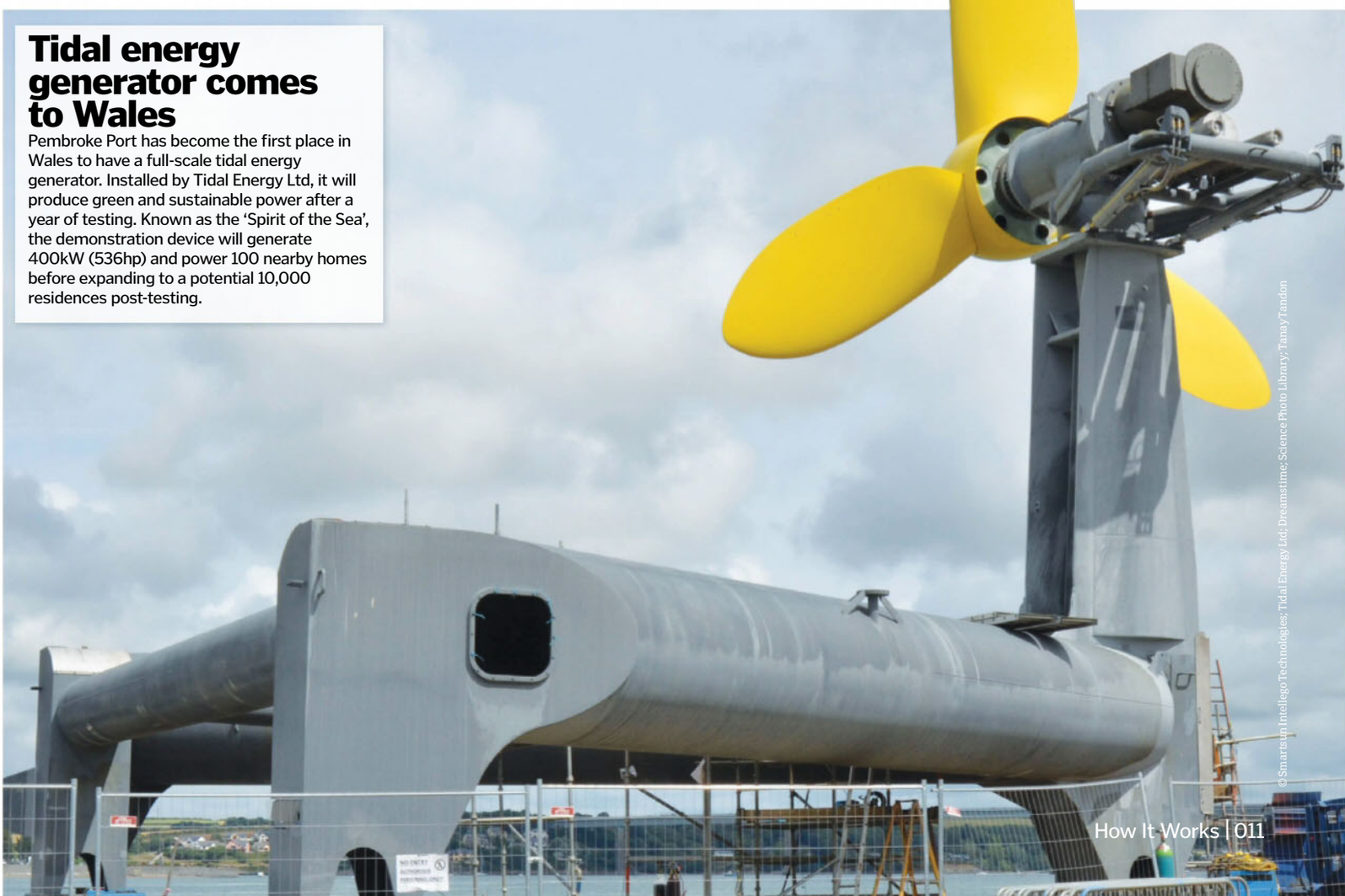
A recent study has revealed that we owe burrowing animals much more than we previously thought. By digging into sediment and exposing it to oxygen-rich water, the first worms stabilised the amount of oxygen on Earth around 540 million years ago. The newly oxygenated bacteria began to take in more phosphate, which left the environment with more O_2. So to only slightly paraphrase the 20-year-old *Lion King*: Slimy but stabilising...

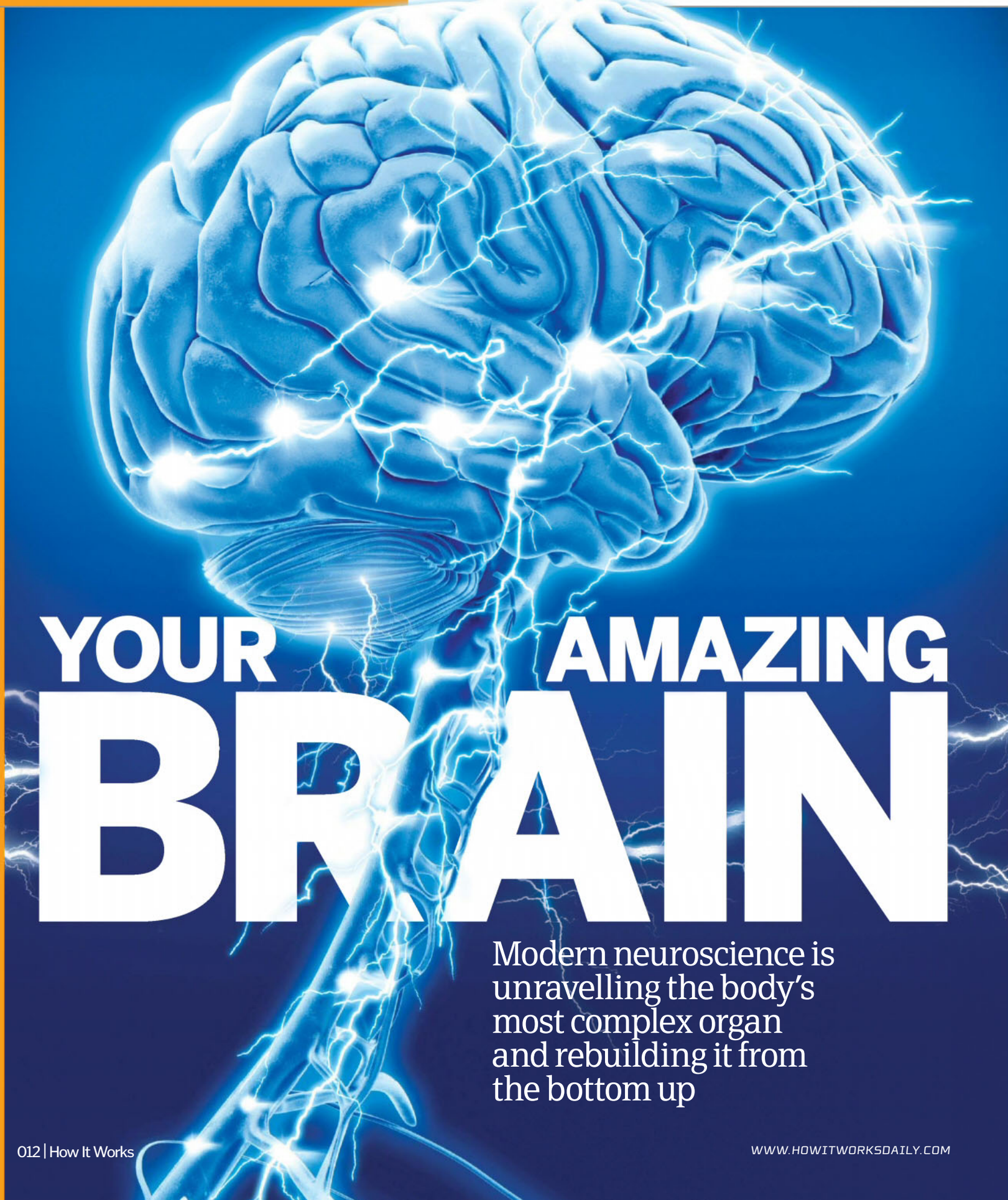
A wristband can alert us to sunburn

A new UV wristband has been developed that will tell you exactly how long you should spend in the Sun's rays before you get burnt. When the band is exposed to UV light, an acid-release agent within it decomposes, changing the colour of the band from yellow to pink. When it changes, you're in danger of getting burnt.

Tidal energy generator comes to Wales

Pembroke Port has become the first place in Wales to have a full-scale tidal energy generator. Installed by Tidal Energy Ltd, it will produce green and sustainable power after a year of testing. Known as the 'Spirit of the Sea', the demonstration device will generate 400kW (536hp) and power 100 nearby homes before expanding to a potential 10,000 residences post-testing.





YOUR AMAZING BRAIN

Modern neuroscience is unravelling the body's most complex organ and rebuilding it from the bottom up

5 TOP FACTS
BRAIN CELLS

1 Neurone
When we think of the brain, the first cell that comes to mind is the nerve cell. The average human brain has 86 billion neurones.

2 Tracking device
These cells produce a fatty substance called myelin. This surrounds the axons of neurones in the brain, providing insulation similar to the plastic wire on an electrical cable.

3 Astrocytes
These star-shaped cells provide support to the other cells of the brain, assisting with biochemical processes, guiding growing nerves, directing scarring and repair after injury.

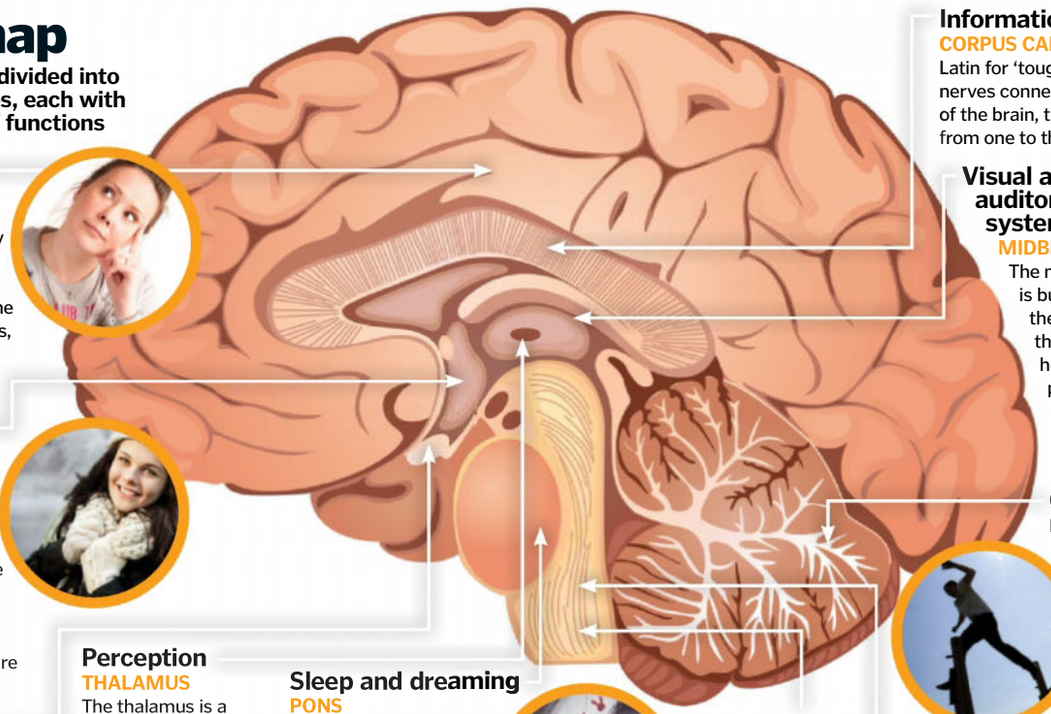
4 Microglia
The brain is sealed off from the immune system, but specialist cells, microglia, are present for protection. They are inactive most of the time to prevent accidental damage to the brain.

5 Endothelial cells
The capillaries that supply blood to the brain are lined with these. They are tightly connected to one another, to restrict movement of chemicals in and out of the brain.

DID YOU KNOW? *When Albert Einstein died in 1955, pathologist Thomas Harvey stole his brain, cut it up and preserved it in jars*

Brain map

The brain can be divided into distinct structures, each with a specialist set of functions



Memory
CEREBRUM
The cerebral cortex makes up the majority of the human brain. It is divided into four lobes, which handle the most complex of tasks, including planning, memory and vision.

Temperature and hydration
HYPOTHALAMUS
The hypothalamus is responsible for maintaining equilibrium within the body. It monitors and adjusts a variety of vital parameters, like the body's temperature and hydration.

Hormones
PITUITARY GLAND
This pea-sized gland is connected to the hypothalamus and produces hormones, passing on chemical messages instead of electrical impulses.

Perception
THALAMUS
The thalamus is a switchboard for sensory information, connecting the parts of the brain and body involved in perception and movement. It also controls the sleep/wake cycle.

Sleep and dreaming
PONS
The pons is another relay station within the brain, allowing nerves in the cerebellum to contact those in the cortex. The pons also plays an important role in the sleep cycle and dreaming.

Breathing
MEDULLA
The medulla is responsible for the involuntary functions that keep us all alive, like breathing, swallowing and heartbeat.

Information transfer
CORPUS CALLOSUM
Latin for 'tough body', this wide sheet of nerves connects the left and right sides of the brain, transferring information from one to the other.

Visual and auditory systems
MIDBRAIN
The midbrain is buried near the centre of the brain and is home to part of the reward pathway, responsible for reinforcing positive behaviours and addiction.

Coordinated movement
CEREBELLUM
Cerebellum means 'little brain.' It is the control centre for coordinated movement, making fine adjustments before the signals are sent to the body.

Connects nerves
BRAIN STEM
The brain stem marks the end of the brain and connects the nerves to the spinal cord. It contains two distinct structures, the pons and the medulla.

The human brain is the most complicated structure in the known universe. It has taken hundreds of millions of years of evolution to construct, and over the last seven million years, it has tripled in size. It weighs little more than a bag of sugar, but packed inside it are 86 billion neurones, linked together by over 100 trillion connections in a network more powerful than even the most advanced supercomputers ever built.

By far the largest part of the human brain is the forebrain, and like the brains of other mammals, it is covered in a thick layer of neurones known as the cerebral cortex. But in humans, this layer has been massively expanded. The human cerebral cortex has 1,000 times as many neurones as the same structure in a mouse, and it has not yet stopped evolving.

The smallest processing units in the cortex are known as neocortical columns, where each contains thousands of different connections. Over the course of evolution, these neocortical columns have been duplicated over and over again, until space in the skull started to run out. The cortex developed deep ridges and folds to fit more and more processing power into the same tiny space, and if unfolded, would cover an area measuring two square metres (21.5 square feet).

The neurones that make up the brain crisscross over one another in a vast network and each individual cell makes up to 10,000 connections, building the most complex circuit in history.

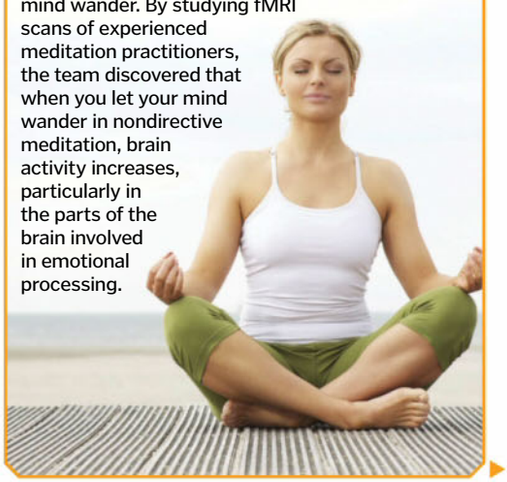
In 2013, a team at the Centre for Regenerative Therapies in Dresden, Germany, examined the formation of neurone connections in cloned mice. They wanted to learn how much the structure of the brain is influenced by life experience. Because the mice were clones, each was genetically identical, meaning that any differences in their brains would be purely down to their environment. The mice lived in large cages, with lots of toys and places to explore, and after just a few months, differences became apparent in their brains. The most excitable, outgoing, curious mice had many more new nerves and new connections than their lazier counterparts; their brains had adapted as they learnt.

While the underlying fabric of the brain is the same, every neurone in every brain is different, and each makes its own unique path. Every

Finding peace

Meditation has been practiced for thousands of years as a means to relax, think, or to find enlightenment. Now, an international team of researchers, based in Norway and Australia, are collaborating to understand why it is such a powerful tool.

There are two types of meditation; concentrative, where a person focuses on specific thoughts; and nondirective, where they let their mind wander. By studying fMRI scans of experienced meditation practitioners, the team discovered that when you let your mind wander in nondirective meditation, brain activity increases, particularly in the parts of the brain involved in emotional processing.



"Projects like EyeWire provide a biologically accurate picture of what is going on inside the human brain"

brain is wired differently, and the unique set of connections is based on experiences.

Mapping the connections in the human brain is an enormous task and work is ongoing. The Human Connectome Project, launched in 2009, is designed to map the intricate connections between all of the neurones in the human brain, in an effort analogous to the Human Genome Project. Computers can be programmed to trace the paths of neurones through brain-scan images, but even the most advanced machines make mistakes, and everything has to be double-checked by a human.

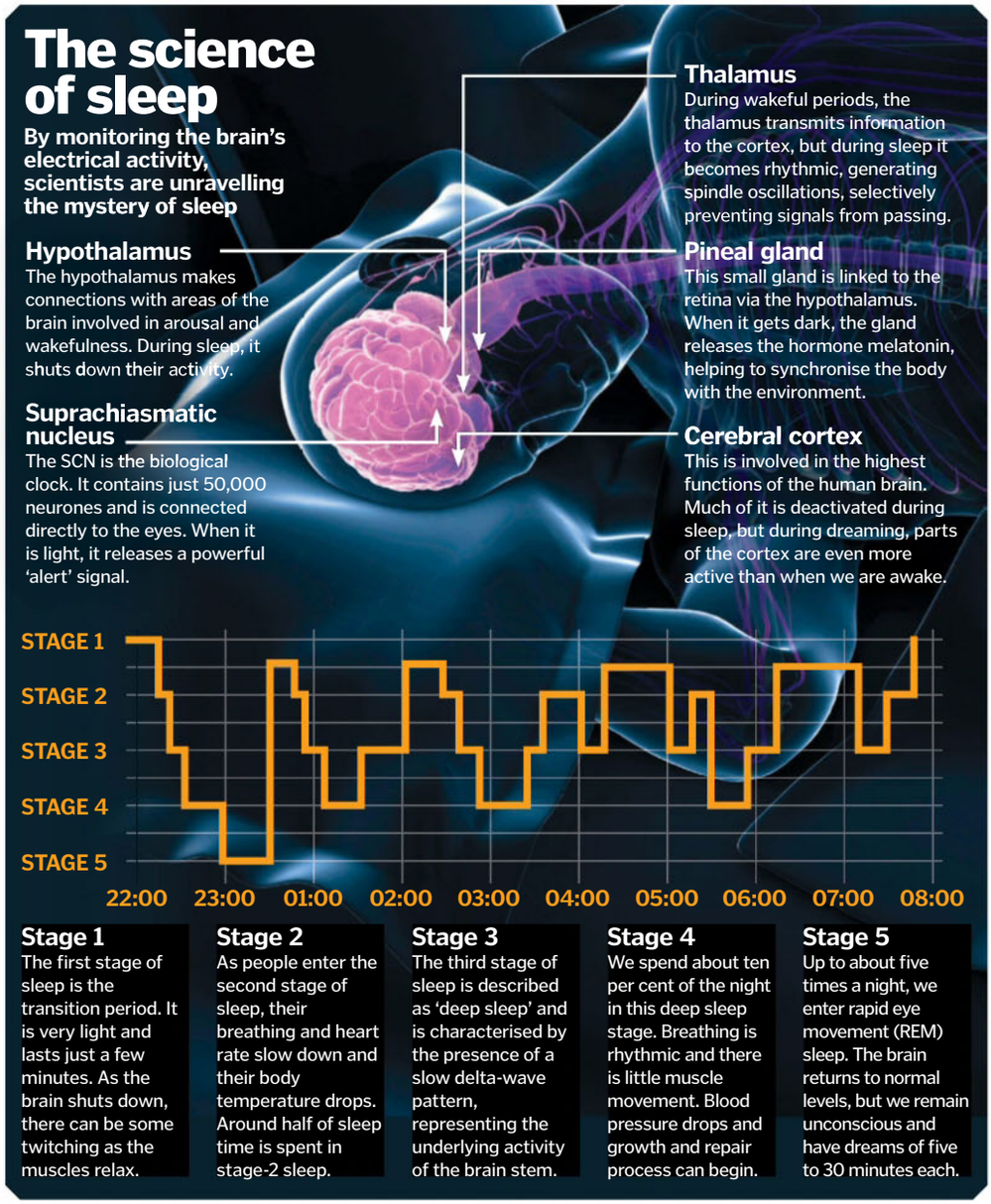
As an alternative, some research teams are trying a new approach, where instead of using computers to analyse the data they are using volunteers. In 2011, the online game *Foldit* made the headlines when players managed to solve a decade-old biological question. By tapping into the spatial skills of videogamers, researchers used volunteers to solve three-dimensional protein puzzles that a computer would struggle to complete. By simply playing the game, hundreds of people worked together to help solve the structure of a protein made by a simian retrovirus that causes AIDS-like symptoms in monkeys.

This approach is now being extended to the field of neuroscience and crowd-sourcing is being used to map the connections between neurones in the back of the eye. Tracking the intricate pathways of neurones in the brain is a difficult task for computers, but people are much better at spotting patterns.

EyeWire is a project designed to map the nerve connections in the human retina. Players are given a half-finished neurone and asked to work through slices of the brain, colouring in the connections. Each cube section is manually checked multiple times by different people, so

The science of sleep

By monitoring the brain's electrical activity, scientists are unravelling the mystery of sleep



Thalamus
During wakeful periods, the thalamus transmits information to the cortex, but during sleep it becomes rhythmic, generating spindle oscillations, selectively preventing signals from passing.

Hypothalamus
The hypothalamus makes connections with areas of the brain involved in arousal and wakefulness. During sleep, it shuts down their activity.

Pineal gland
This small gland is linked to the retina via the hypothalamus. When it gets dark, the gland releases the hormone melatonin, helping to synchronise the body with the environment.

Suprachiasmatic nucleus
The SCN is the biological clock. It contains just 50,000 neurones and is connected directly to the eyes. When it is light, it releases a powerful 'alert' signal.

Cerebral cortex
This is involved in the highest functions of the human brain. Much of it is deactivated during sleep, but during dreaming, parts of the cortex are even more active than when we are awake.

Stage 1
The first stage of sleep is the transition period. It is very light and lasts just a few minutes. As the brain shuts down, there can be some twitching as the muscles relax.

Stage 2
As people enter the second stage of sleep, their breathing and heart rate slow down and their body temperature drops. Around half of sleep time is spent in stage-2 sleep.

Stage 3
The third stage of sleep is described as 'deep sleep' and is characterised by the presence of a slow delta-wave pattern, representing the underlying activity of the brain stem.

Stage 4
We spend about ten per cent of the night in this deep sleep stage. Breathing is rhythmic and there is little muscle movement. Blood pressure drops and growth and repair process can begin.

Stage 5
Up to about five times a night, we enter rapid eye movement (REM) sleep. The brain returns to normal levels, but we remain unconscious and have dreams of five to 30 minutes each.

The developing brain

Baby
In order to fit through the birth canal, human babies must be born well before their brains have finished developing, so their brains grow rapidly in their first years. Experiences prompt the development of new connections between nerves, and by the time a baby is two years old, it has 1.5 times as many synapses as an adult.

Infant
Support cells, known as glia, provide protection, insulation and nutrition for the brain's nerve cells. Throughout childhood, they continue to migrate and grow. During the first two to three years of a child's life, the insulating white matter of the still-developing brain begins to form.

Child
By the age of ten or 11, the rapid development of new connections in the brain has ended and a period of trimming and pruning begins. Instead of creating extra pathways, the brain focuses in on the most important, strengthening and insulating those that are used more often and losing ones that are no longer valuable.

NEURONES **86 billion**
OXYGEN USAGE 20%
LENGTH 17cm
1.4kg MASS
SYNAPSES 100 trillion
PART OF BODY WEIGHT 2%

DID YOU KNOW? *You sleep for around a third of your life and have around five dreams every night*

Making memories

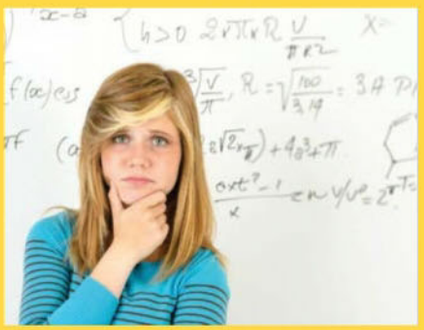
The human brain has an amazing capacity for retaining information

SENSORY MEMORY
The body is constantly bombarded by sensory signals and most incoming sensory information is retained for less than a second before it is forgotten.

TRANSFER
The hippocampus integrates incoming sensory information, collecting it together as a single experience. It works together with the cortex to prioritise which information to store and which to forget.

SHORT-TERM MEMORY
Without concentrating too hard, short-term memory can hold around seven items for 20 to 30 seconds. Collecting information into discrete chunks, like splitting a phone number up into sections, can help the brain retain more.

IMPLICIT MEMORY
These types of memories do not require conscious recall and are often based on motor skills. By repeating tasks, like riding a bike or playing the piano, pathways become automatic.



EXPLICIT MEMORY
Explicit memories are accessed consciously. They can be stored as episodes, linked to a specific event or place, or stored by category as more abstract knowledge.

RECOGNITION
The brain is very good at making associations, and incoming information is compared to stored data, allowing us to quickly recall things we already know or have experienced before.

ASSOCIATION
Memories are rarely stored in isolation and one pathway is linked to others. Recognition and recall can both trigger other related memories.

RECALL
Human memory is associative; it works by linking pieces of information together. Memories are not stored as individual entities, but reconstructed using several different parts of the brain.

NEURONE CHANGES
If a synapse is used repeatedly, it becomes increasingly sensitive to stimulation, producing more receptors and strengthening the connection.

ACOUSTIC ENCODING
Short-term memory tends to be based on sound, also known as echoic memory. When trying to remember a phone number, it often helps to rehearse it vocally in your head.

CONSOLIDATION
Once the trace of a memory is formed, the pathway can be consolidated with use. The more often a synapse is used, the stronger it becomes.

LONG-TERM MEMORY
The hippocampus is essential for the transfer of memories from short to long-term storage. Some of this memory consolidation happens in dreaming as the brain rehearses the day's activities.

SEMANTIC ENCODING
Instead of being linked to an audio memory, long-term memories tend to be stored more abstractly, by concept. Other memories are stored as sensory echoes, allowing entire experiences to be remembered and reconstructed.

Teenager
Trimming and adjusting the brain starts at the back and works forward, continuing into the teenage years. The prefrontal cortex, involved in planning, judgement and emotional control, is the last to be finished. Research also suggests that adolescents' body clocks are wired differently, so they naturally go to bed and wake up later.

Adult
Most growth and remodelling is complete by our early-20s, but new connections continue to form in the adult brain, albeit at a much slower rate than in children. Staying active and providing the brain with engagement and stimulation strengthens existing connections, and new pathways continue to form as we learn.

Old age
Damage to the brain cannot easily be repaired, so as it ages, signs of wear start to appear. Connections are lost as nerve cells wither, or as debris builds up between synapses, and gradually mental function can decline, leading to age-related illnesses like Alzheimer's disease and Parkinson's.

"At the University of California [...] researchers are using electricity to selectively erase memories"

if someone makes a mistake it is averaged out by the community. More experienced players oversee the work and can make changes if they feel they are needed. This approach speeds up the process by thousands of times.

Although projects like EyeWire provide a detailed and biologically accurate picture of what is going on inside the human brain, rebuilding the entire structure using this method will still take decades. The alternative is to simulate the brain, taking what we already know and using it as a scaffold to build the parts we have yet to study. By going back and testing the model brain against the real data, scientists can check that their simulation is working as it should.

Japan's K Computer is one of the fastest and most powerful in the world, and in 2014, 83,000 of its processors were combined in order to simulate one per cent of one second of human brain activity. This was a huge achievement, but it took the machine 40 minutes and barely represented a fraction of the power of the human brain.

The problem is that most modern computers are built on architecture completely different to the human brain. The brain is made up of processing cores, capable of specialising to perform highly specific tasks. They are less precise, but have much more flexibility, and most importantly, the capacity to learn. Memories are not stored in one particular place, and are instead distributed across the network. In contrast, modern computers use programs in order to decide what to do, and they store elements in a hierarchical memory.

In 2013, the European Commission funded the Human Brain Project with a grant of €1 billion (£800 million/$1.3 billion) in order to accomplish just that. This ambitious, ten-year endeavour aims to develop cutting-edge computational tools to assist in the understanding of brain function, bringing together the fragments from different disciplines and providing an unprecedented map of human brain activity. The Human Brain Project hopes to use this information to build a supercomputer capable of simulating the network that makes up the human brain. They estimate that it would take one laptop to simulate the activity of one neurone and are working closely with IBM to develop powerful neuromorphic supercomputers.

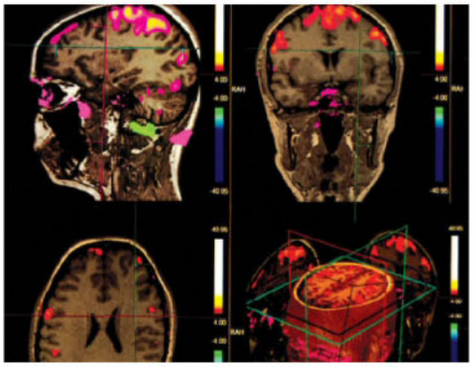
Neuromorphic chips are computer chips modelled on the architecture of the human brain. IBM released a chip modelled on the human brain in 2014. Known as the SyNAPSE chip, it has one million 'neurones' connected by 256

Imaging the brain

Take a look at the most common techniques used to study the living brain

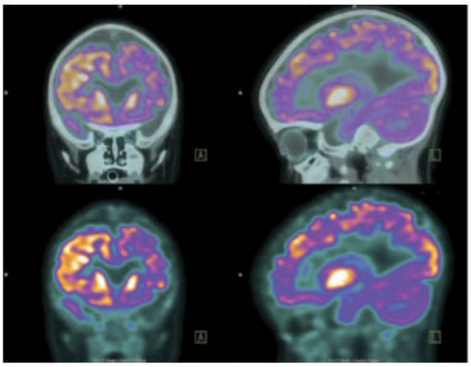
CT

Computed tomography (CT) scans use X-rays to build a three-dimensional image of the brain. The radiation travels at different speeds through different tissues, allowing a density map to be produced. It provides purely structural information and is useful for identifying tumours.



fMRI

Functional Magnetic Resonance Imaging detects the amount of oxygen present in the blood, allowing brain activity to be mapped. When regions of the brain become more active, their demand for blood rises and they light up on the image. It captures a picture of the activity of the entire brain every two seconds.

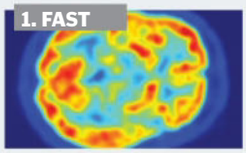


PET

Positron Emission Tomography uses safe radioactive isotopes to measure brain activity. By labelling oxygen or sugar with radioactive tags, blood flow in the brain can be monitored. The tags emit low-energy radiation and as blood is diverted to active regions of the brain, the emissions pinpoint the locations.

EEG

Electroencephalograms take advantage of the electrical signals produced by nerves to produce a map of brain function. Electrodes placed on the scalp are able to detect the patterns of nerve activity beneath the surface. This technique is particularly useful for sleep studies.



PET
Compared to other imaging techniques, radiation-based methods like PET scans are relatively slow, where it takes several minutes to complete a scan.

fMRI
Functional MRI captures an image of the activity of the brain every two minutes, allowing changes to be monitored closely.

Magneto-encephalopathy
Using sensitive magnetometers, scientists are able to record the electrical activity of the brain in real-time.

DID YOU KNOW? *A human brain weighs around four times as much as a chimpanzee's brain*

Brain damage

Different injuries affect the brain in different ways

SEVERE
If the injury is severe, the patient is no longer able to respond to sensory stimulation. Their eyes remain closed and there is no response at all to verbal cues.

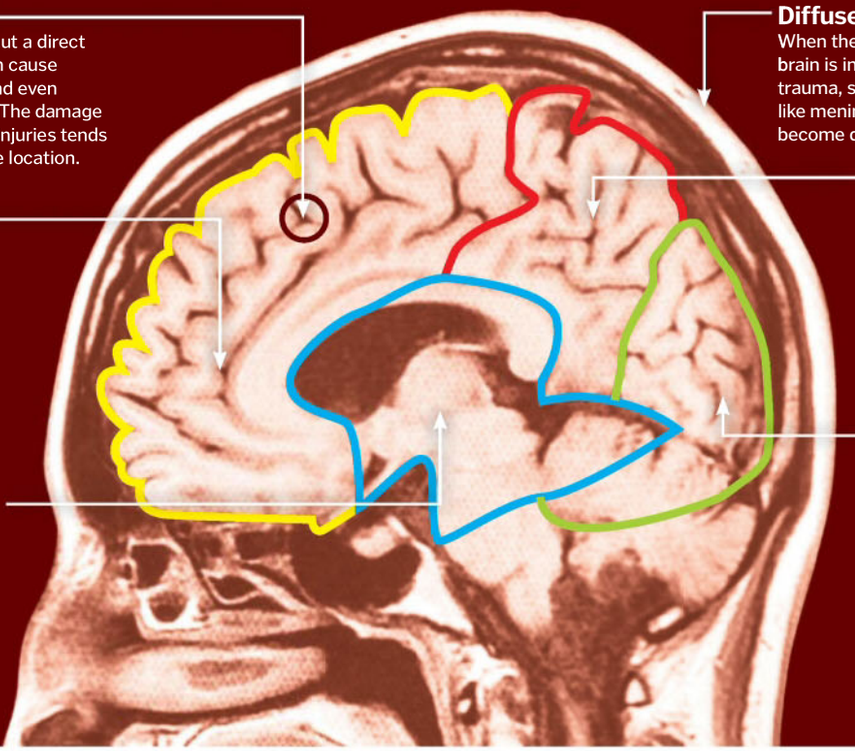
MODERATE
When brain injury is more severe, verbal communication starts to break down and patients no longer respond normally to pain.

MILD
With mild brain injury, patients may be confused, but they remain aware, conscious and conversational.

Focal injury
The skull is strong, but a direct blow to the head can cause bruising, bleeding and even penetrate the brain. The damage from these kinds of injuries tends to be focused on one location.

Frontal lobe
Damage to the frontal lobes affects higher cognitive functions like reasoning, social interactions and emotional regulation.

Temporal lobe
Damage to the temporal lobes can interrupt the formation of visual and long-term memories, as well as processing incoming sensory information.



Diffuse injury
When the blood supply to the brain is interrupted, by trauma, stroke, or infections like meningitis, large areas can become damaged.

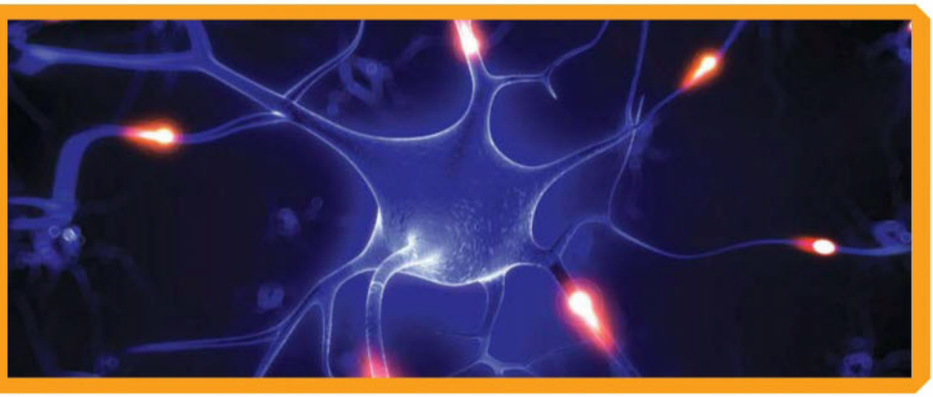
Parietal lobe
Damage to the parietal lobes affects spatial awareness and the ability to understand the three-dimensional environment, either visually or by touch.

Occipital lobe
The occipital lobe is responsible for vision, so injury to the back of the head can result in visual problems, ranging from temporary blurring through to 'seeing stars' and to permanent blindness.

Can the brain heal?

The human brain has limited capacity for repair, so once a region is injured, it cannot be replaced. The damaged cells are removed and support cells known as astrocytes divide to form a wall around the gap to seal off the area. The space then becomes filled with fluid. However, all is not lost.

The human brain is a remarkable organ and although it cannot repair itself as such, it is able to adapt. Nerves are not fixed in their function, or their connections, so if a part of the brain is injured, new connections can be made to bypass the damage. The amount of function that can be regained depends on the location and severity of the injury and can be greatly aided by rehabilitation, encouraging the formation of new pathways in the brain.



million 'synapses.' They are arranged into 4,096 'synaptic cores', which function in parallel with one another, just like the processing cores in the brain. Just like the brain, they operate on demand and can compensate if one core happens to fail.

By feeding these computers with inputs that mimic biological signals, scientists can then examine the electrical activity and can see where information is being processed and stored. The project is a collaboration between over 100 institutions in 24 countries.

New technology is the key to modelling a structure as complex as the human brain, and other international efforts are also in place to provide new technology. In 2013, US President Barack Obama announced the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative. The NIH (National Institutes of Health) will allocate £24 million ($40 million) in 2014 to develop new technologies to find the best way to understand the brain. In order to break the brain down and rebuild it accurately, the project will combine silicon-based techniques and advancements in stem-cell biology, brain imaging and medical drug development.

The practical applications of this future technology are incredible, but we are already able to interface with the brain in more ways than ever before. Light-sensitive retinal implants can restore sight to the blind by sending electrical signals to the optic nerve, while auditory brainstem implants communicate sound signals directly to the brain in patients who are profoundly deaf.

However, one of the most incredible technological developments of all is the BrainGate system, first revealed in 2006 and now undergoing clinical trials. The technology uses a sensor implanted on the motor cortex of the brain to pick up electrical signals generated when the patient thinks about moving. These signals are then decoded by a computer program and sent to a ▶

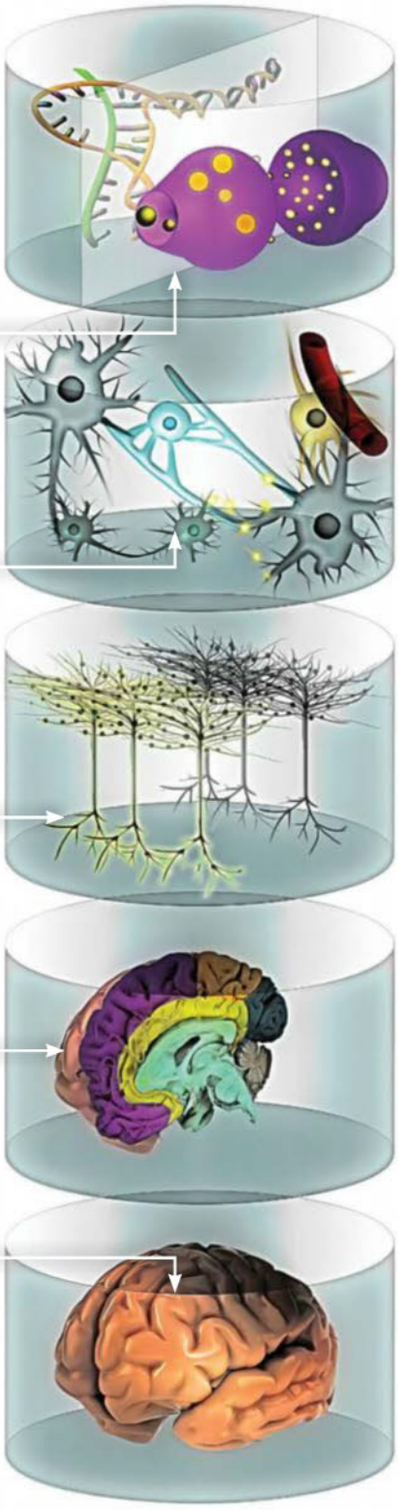
"Player one thinks about firing the cannon, and fractions of a second later, player two pushes the button"

Cutting-edge neuroscience

The human brain is one of the most complex structures in the known universe and understanding how it works is an enormous scientific undertaking. Modern neuroscience brings together experts from a huge array of fields and by using a combination of the most advanced technologies, medical techniques, biological research and computational modelling, scientists are finally beginning to untangle the many profound mysteries of the human brain.

Building a brain

Large-scale projects aim to simulate the human brain at every level



DNA and neurotransmitters

At the molecular level, scientists are able to manipulate the 3D structures of proteins using computer programmes, and to model the effects that changes might have. Such techniques are hugely useful in drug design.

Nerves and support cells

In order to gain a proper understanding of how the brain functions, many scientists advocate a bottom-up approach. By creating digital neurones based on the underlying rules and principles of biology, it is hoped that the complex network of the brain can be simulated.

Neural pathways

Some projects aim to map all of the connections in the human brain, generating a 3D representation of the intricate wiring. Others aim to simulate the process, allowing the computer to make its own connections based on biological rules.

Lobes and structures

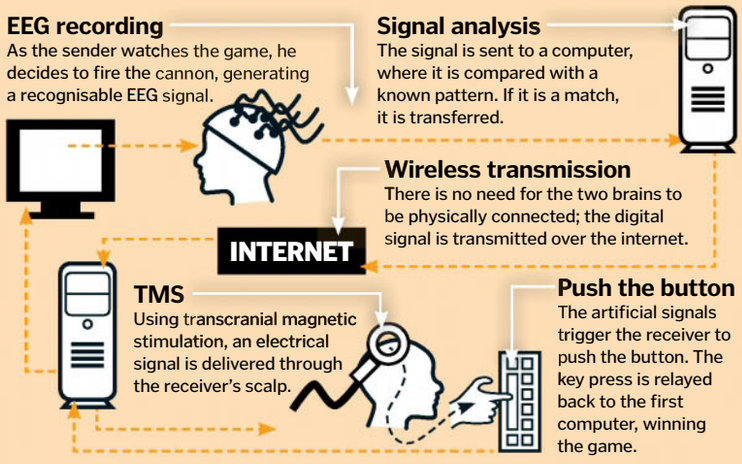
Simulations will allow information about different structures in the brain to be integrated, enabling scientists to more closely examine the interactions between different areas, or even to remove one region and study it in isolation.

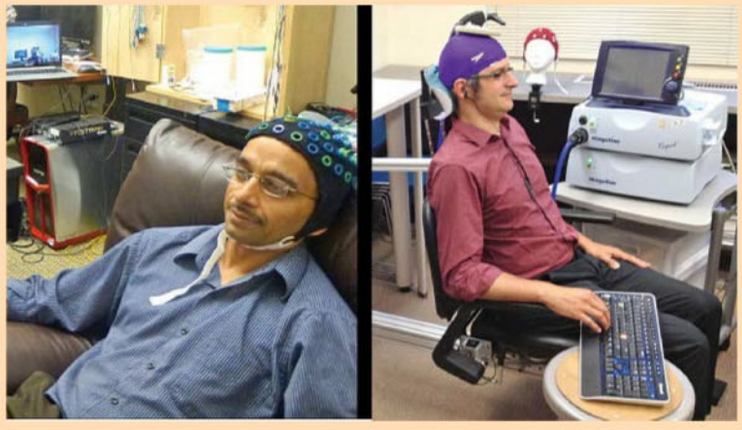
Whole brain

In 2013, the K Computer in Japan carried out one second of simulated human brain activity. With 705,024 processor cores, it took the machine 40 minutes to simulate a network just one per cent of the size of the human brain. Advanced processors due in the next ten years will increase this capability significantly.

How mind control works

Simple equipment and complex computer programming allow our thoughts to be transmitted over the internet





Mind control

In a groundbreaking experiment in 2013, researchers at the University of Washington successfully linked two human brains together and proved their principle with a video game.

The city is under attack by pirates, where player one, the sender, must intercept their rockets. They can see the screen and are armed with a cannon, but they do not have a keyboard and cannot press 'fire'. Player two, the receiver, is sitting in another room; he cannot see the game, but he does have a keyboard. Player one thinks about firing the cannon, and fractions of a second later, player two pushes the button, saving the city and winning the game.

Player one was wired up to an electroencephalogram (EEG) and his brain activity was being monitored. When he was thinking about pressing the button, there was a characteristic signal in the 'mu band' of the EEG, triggering the program to send a wireless signal to player two.

Player two was wearing a specially designed coil on his scalp that generated a magnetic field, positioned over the part of the brain that controls contraction in the right hand. The signal from player one was converted into magnetic stimulation, which in turn triggered electrical activity in the brain, causing player two to involuntarily fire the cannon.

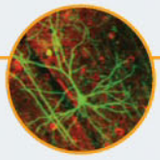
KEY DATES
HISTORY OF NEUROSCIENCE

1700 BCE
An Egyptian surgeon records details of his patients, producing the first written example of the word 'brain.'

130-200 CE
Greek surgeon Galen suggests the brain is responsible for sensory perception and the control of movement.

1837
Czech Johannes Purkinje describes a nerve cell for the first time; the large, branching neurones of the cerebellum.

1861
Pierre Paul Broca identifies the region of the brain responsible for speech, now known as 'Broca's area.'



1906
Camillo Golgi and Santiago Ramón Y Cajal share the Nobel Prize for demonstrating that the brain is a network of neurones.

DID YOU KNOW? *Your brain produces enough electricity to power a light bulb and consumes 20% of the oxygen you take in*

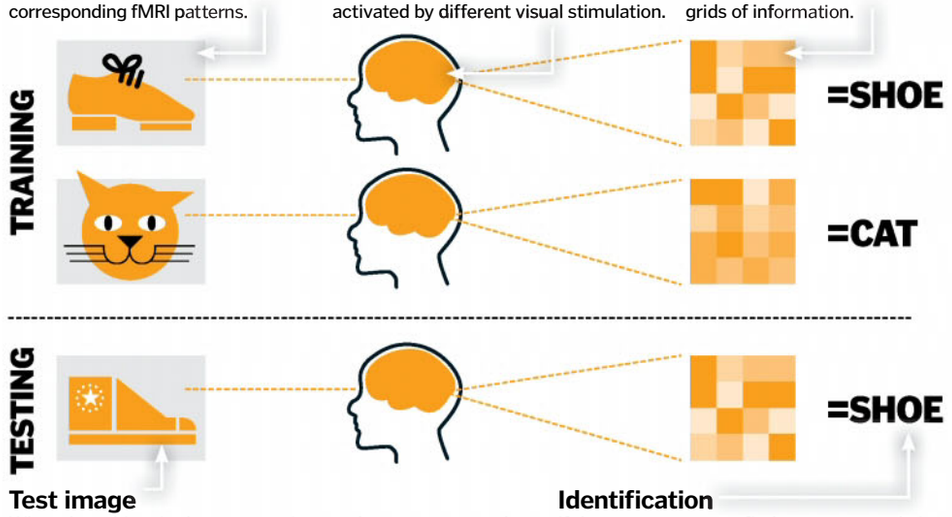
Decoding the brain

Computer programmes can learn to decode brain-scan data and essentially read our thoughts

Training images
The program is trained using a series of images, alongside their corresponding fMRI patterns.

fMRI scan
Functional magnetic resonance imaging is used to identify the parts of the brain activated by different visual stimulation.

Voxel pattern
The fMRI data is stored as voxel patterns, three-dimensional grids of information.



Test image
When the subject is shown a new image, the program searches through its training database to find the nearest match.

Identification
If the program cannot find an exact match, it will use its training data to find a best estimate.

A machine that can read your mind

Have you ever wished someone else could see what you can see? A team at the University of California, Berkley, have developed a program that can tell what film you are watching just by reading your brain activity. The program can even read the exact image you see and display the moving mental images on a screen.

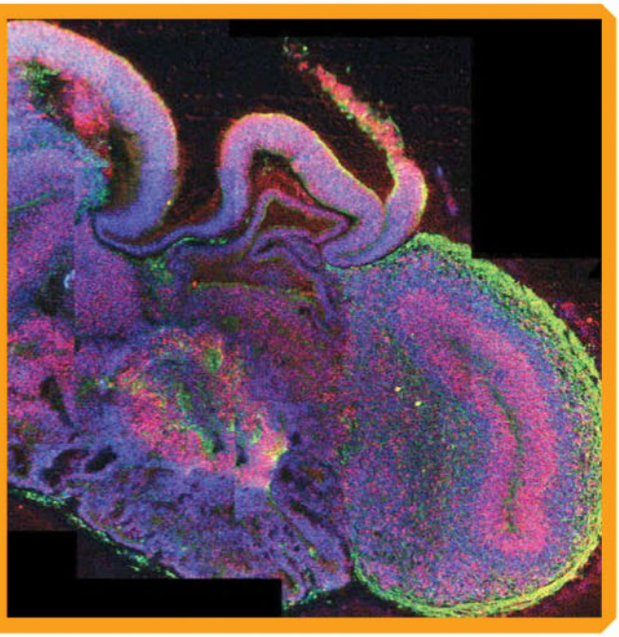
Volunteers were shown hours of video clips and for each one, their brain activity was mapped using functional magnetic resonance imaging (fMRI). The program was then trained to associate patterns of brain activity with their corresponding images.

Using this data set as a reference, the program was the shown new fMRI data recorded as people as they watched unknown clips. The program was able to compare the new data against its training data and guess what the test subject was watching by compiling and averaging the closest matches in to moving collages. The resulting pictures were eerily close to the original clips.

Growing a brain

In 2013, scientists at the Austrian Academy of Sciences achieved something incredible; they grew part of a human brain in a Petri dish. Using a combination of embryonic stem cells and stem cells taken from adult skin, the team recreated the neuroectoderm; the embryonic structure that goes on to form the brain and the spinal cord.

The cells were put in three-dimensional scaffolds to give them something to grow around, and then given nutrients and oxygen and allowed to develop. Amazingly, the structures organised themselves into something resembling the brain of a nine-week old foetus. Some contained the pigmented cells of a retina, others developed a cortex and some even had a hippocampus. These mini-brains are about the size of a pea, and incapable of conscious thought, but could provide a valuable tool for researchers.



Get involved with EyeWire

Citizen scientists are needed to help untangle the neurones of the human retina

Developed by the Seung Lab at MIT, this browser-based game, known as EyeWire, is a project designed to map the neurones of the retina. Anyone can play; all you need is a computer and an internet connection.

EyeWire is a 3D puzzle game based inside a cube. The cube is divided into slices and hidden within them is the path of a neurone. All you have to do is scroll through and connect the slices together, tracing the path of the nerve cell through the cube.

As you work, a 3D model of your progress appears to the side of the screen and you can earn points based on how closely your model matches the models made by other players. You can earn points, level up and even participate in weekly competitions.

Every time you play, you are mapping actual neurones from the human retina, making a real contribution to scientific research.

prosthetic limb. By carefully training the program to recognise specific signals, patients are able to move their bionic hands using just the power of their brains.

Taking electrical brain interfaces one step further, at the University of California, San Diego, researchers are using electricity to selectively erase memories. They have shown that by using particular frequencies of electrical pulses they can produce changes in the nerve cells in the brains of rats, making them forget traumatising experiences in their past.

As we continue to learn more about the connections in the brain, the possibilities for interacting with it will only continue to increase. The field of neuroscience is advancing faster than ever before, and huge international collaborations, like the Human Brain Project and the BRAIN initiative, are bringing mountains of research data together, creating resources that will revolutionise the field of neuroscience.

The puzzle of the human brain has been vexing scientists, doctors, and philosophers for thousands of years and understanding how it works is perhaps the most challenging problem in the history of science. However, with a combination of powerful new technology and international collaboration, the complexity of this mass of neurones is starting to unravel. Very soon, we might even be able to rebuild a functioning digital brain from the bottom up.

"Pollen has to be carried to the female organ called the ovary, usually of another flower"

How plants reproduce

Find out how pollination causes other plants to grow and spread

Pollination is one of the most important natural processes for life to persist on our planet. Without it there would be no fruits or grain crops, no grasslands and the only forests would be of tree ferns or giant horsetails. There would be no butterflies and moths, and dramatically less diversity of birds and mammals.

Pollination is the main process by which higher plants – those are the ones that produce some kind of seed – reproduce and spread. They can also spread their seeds using various forms of buds or creeping stems, but these are asexual processes that produce new plants identical to the parent. Pollination is a sexual process, which ensures variation in the offspring. This provides the opportunity for species to adapt to changing environments and so evolve.

The key to pollination is the flower, which can be tiny as in some grasses and trees or big and showy, depending on the method of pollination. Inside the flower, separate male and female organs form. The male organ is called the stamen, topped by the anther – a brush-like tip where the male sex cells, called pollen, are produced. Pollen has to be carried to the female organ called the ovary, usually of another flower. The ovary has an extended stalk called the style. When pollen reaches the tip of the style, called the stigma, it grows down its length to the female sex cell or ovule in the ovary. The pollen grain and ovule fuse in a process called fertilisation, and develop into the seed.

The seeds can then be dispersed from the parent plant to spread their kind. They might have parachutes or wings to help them spread in the wind, or they might be contained within a succulent fruit, which an animal, like a fly or small bird, might eat and spread the seeds inside in the process.

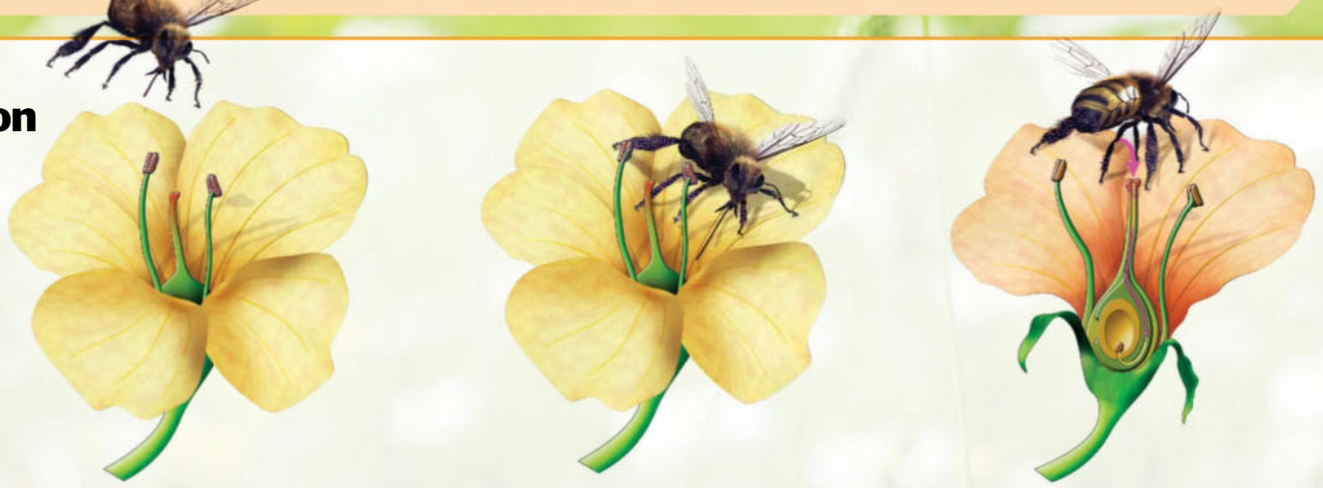
Pollen transfer

To maximise variation and adaptability, pollen ideally needs to be transferred from one flower to the flower of another plant of the same species. There are two main ways of doing this. Some plants are wind-pollinated. Their flowers are usually small and clustered, dangling clear of the plant so they are exposed to the wind. They produce vast amounts of pollen to ensure that some will reach their target. Any hay-fever sufferer knows how widely grass pollen can spread in the wind!

Other plants have brightly coloured and showy flowers, each one specifically designed and evolved to attract a particular kind of pollinating animal. It might be a butterfly, moth, bee or other insect, a bird like a hummingbird or honeyeater, or perhaps a bat, possum or other mammal. The advantage is that these pollinators are most likely to go on to visit another flower of the same species, which is a much more efficient way of ensuring pollination than leaving it to the wind.

A bee that's been covered in pollen

Insect pollination



Floral attraction
A bee is attracted to this flower, perhaps by its scent or its bright colours. Yellow flowers are especially good at reflecting ultraviolet light, which bees see vividly.

Nectar reward
The flower rewards the bee with sweet, sugary nectar at its centre. As the bee sips the nectar, it brushes against the flower's anthers, which dust pollen onto its back.

Pollen transfer
The bee moves to a second flower. As it reaches for more nectar, some purple pollen grains stick to the stigma in the centre of the flower.

5 TOP FACTS
POLLINATION

Long-haul transport
1 The tiny, dry pollen grains of wind-pollinated plants like trees or grasses can be carried 2,700m (8,860ft) into the sky and up to 4,800km (3,000mi) from the parent plant.

Pollen clouds
2 A single catkin of a birch tree can produce 5.5 million pollen grains – and the tree has several thousand catkins! But very few ever reach and pollinate another birch tree.

Buzz pollination
3 Some flowers only release pollen from their anthers to one particular species of bee that buzzes its wings at exactly the right frequency to shake the pollen free.

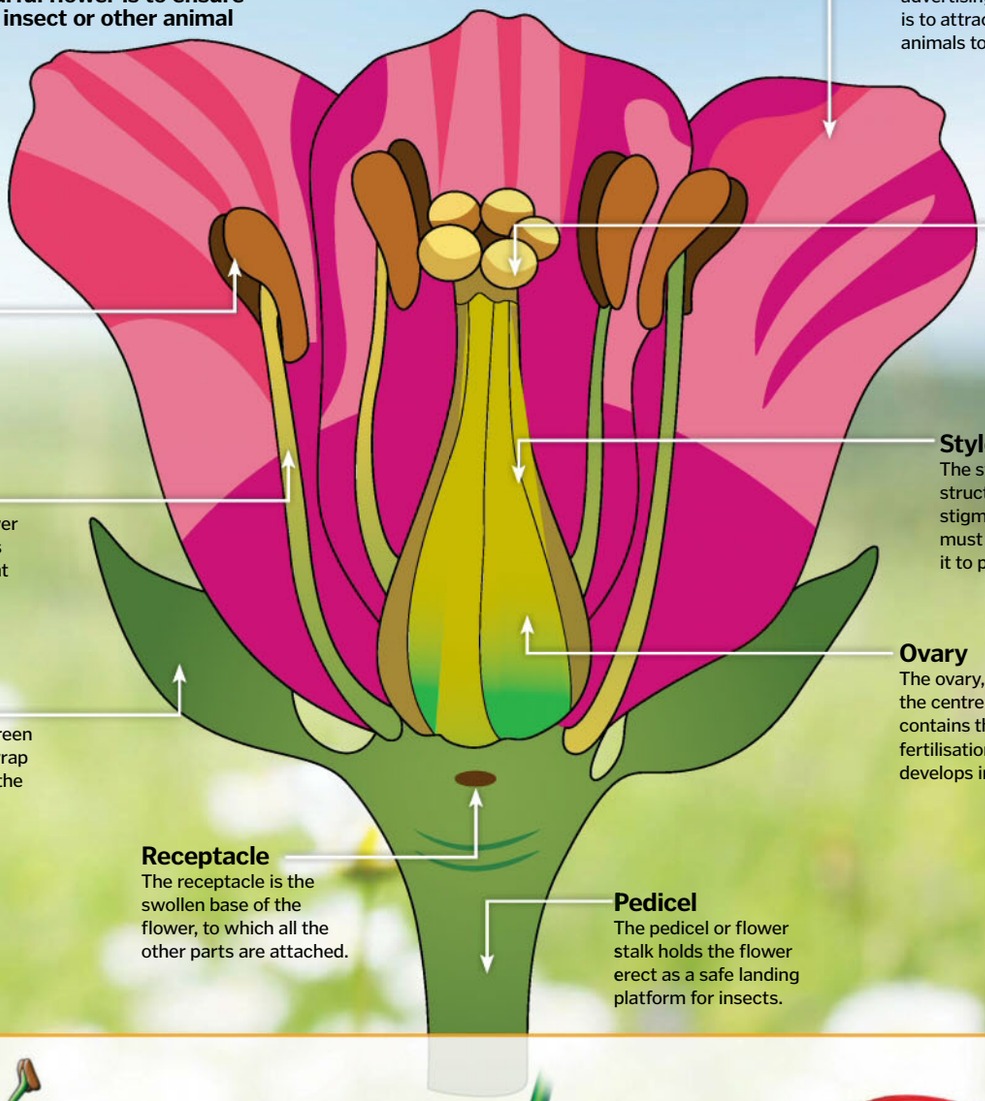
Pollen prison
4 When a beetle enters a Victoria water-lily flower, the petals snap shut. The flower dusts the trapped, struggling beetle with pollen before opening again to release it.

Sex trap
5 Some orchids have flowers that look and smell like females of certain bee species. Male bees try to mate with the flowers, inadvertently transferring pollen.

DID YOU KNOW? *Many flowers are pollinated by birds or bats, and Australia has around 21 species of pollinating marsupials!*

The functional flower

The main function of a colourful flower is to ensure successful pollination by an insect or other animal



Petals
The petals are the flower's advertising hoarding. Their job is to attract insects or other animals to carry out pollination.

Stigma
The stigma is the tip of the female part of the flower, designed to receive pollen from a visiting insect.

Anther
The anther is the fertile part of the stamen. It produces masses of pollen – male sex cells.

Style
The style is a tubular structure beneath the stigma. Pollen grains must grow down through it to pollinate the ovule.

Filament
The male part of the flower is called the stamen. This consists of a filament that holds up the anther.

Ovary
The ovary, protected in the centre of the flower, contains the ovule. After fertilisation, this develops into a seed.

Sepal
Sepals are usually green and leaf-like. They wrap around and protect the flower in bud.

Receptacle
The receptacle is the swollen base of the flower, to which all the other parts are attached.

Pedicel
The pedicel or flower stalk holds the flower erect as a safe landing platform for insects.

Fertilisation
A tube emerges from the pollen grain and grows down through the style to the ovary where it fuses with the ovule. Fertilisation is now complete.

Fertile seed
The fertilised ovule becomes a seed. In this plant, the walls of the ovary swell around the seed, forming a fleshy fruit with the fertile seed at is core.

Fleshy fruit
The sweet red fruit attracts animals that eat the fruit. The seed passes through their digestive system and is deposited on the ground, ready to grow into a new plant.

"A catalyst has the ability to speed up a chemical reaction by providing a surface ideal for a reaction to occur"

Catalysts

What's really at the middle of a chain reaction?

Reactions can be as slow as the acid in your stomach digesting food over a period of several hours, or as quick and dramatic as a piece of magnesium setting alight. However, there are ways you can alter and – to an extent – control the speed of a reaction and that is by using a catalyst.

Much like stepping on the accelerator pedal on a car makes it go faster, using a catalyst has the ability to speed up a chemical reaction by providing a surface ideal for a reaction to occur. Particles are attracted to the surface of the catalyst, allowing many more successful collisions and therefore reactions. Substances that slow down a reaction work the opposite way, reducing the success rate of collisions, and are called inhibitors.

A catalyst will generally be made of a transition metal like iron or nickel because they can comfortably give and receive electrons, a function that is crucial to many chemical reactions.

ABOVE Catalysts can aid the production of oxygen by decomposing hydrogen peroxide

What is dry ice?

How do rock stars and actors get their atmospheric assistance?

If you've ever been to any kind of stage show, there's a decent chance you'll have seen dry ice being used. This is the stuff that's pumped onto the stage to simulate mist and fog, or generally make the place just look awesome, but what is it and how is it made?

Dry ice is actually highly pressurised liquid-carbon dioxide that has been frozen to a temperature of -78.5 degrees Celsius (-109.3 degrees Fahrenheit). The main benefit of using carbon dioxide is that when it warms up it sublimates, which means it changes from solid to gas without becoming a liquid. So if you warm it up and pump it across a stage, it will turn instantly to cool-looking mist, rather than just soaking the floor.

It is also really useful for packing frozen goods that need to stay cool because when it warms up, it turns gaseous rather than wet.

Making dry ice

20.65m³

BIGGEST FREE-FLOATING SOAP BUBBLE

On 27 April 2013, the USA's Megan Colby Parker created the world's largest outdoor free-form soap bubble, which measured 20.65m³ (729.25ft³). That's big enough to fit over 13 vending machines inside.

DID YOU KNOW? *The lack of gravity in space means you can form a bubble with a wand using just water*

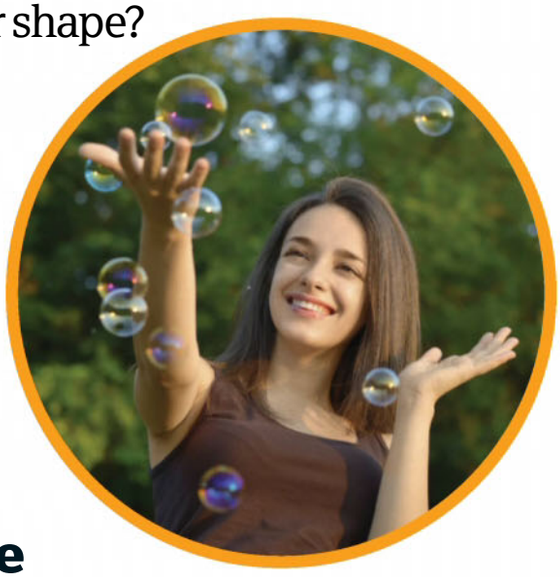
How do bubbles form?

How do these stunningly simple structures hold their shape?

Whether it's by frothing the washing-up liquid in the sink or blowing a mixture through a hoop, bubbles are both stunning and short lived, but how are they created in the first place?

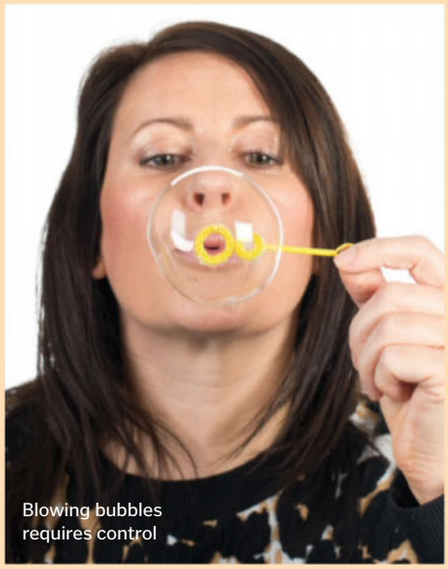
It's all to do with the soap molecules. Each molecule of soap has two poles, one side that loves being next to water (hydrophilic) and one side that completely hates it (hydrophobic). So when you mix soap and water, half of it is trying to escape the water and half is trying to get as close to it as possible. A bubble is formed when a thin film of soap and water surrounds a pocket of air. Water is trapped between two layers of soap molecules, which are attached to the water by the water-loving pole. This makes the structure firmer and self-supporting as both layers of soap are clinging to the water with no way for the air inside to escape.

Bubbles will always form a sphere because that is the shape with the least surface area for a set volume, making it easier for the bonds to form. This is also why, when two bubbles meet, they squash together. The reason for this is that they are trying to form a single wall and, again, reduce the surface area. If you are careful, you can patch lots of bubbles together to make a hexagonal pattern.



How to blow perfect bubbles

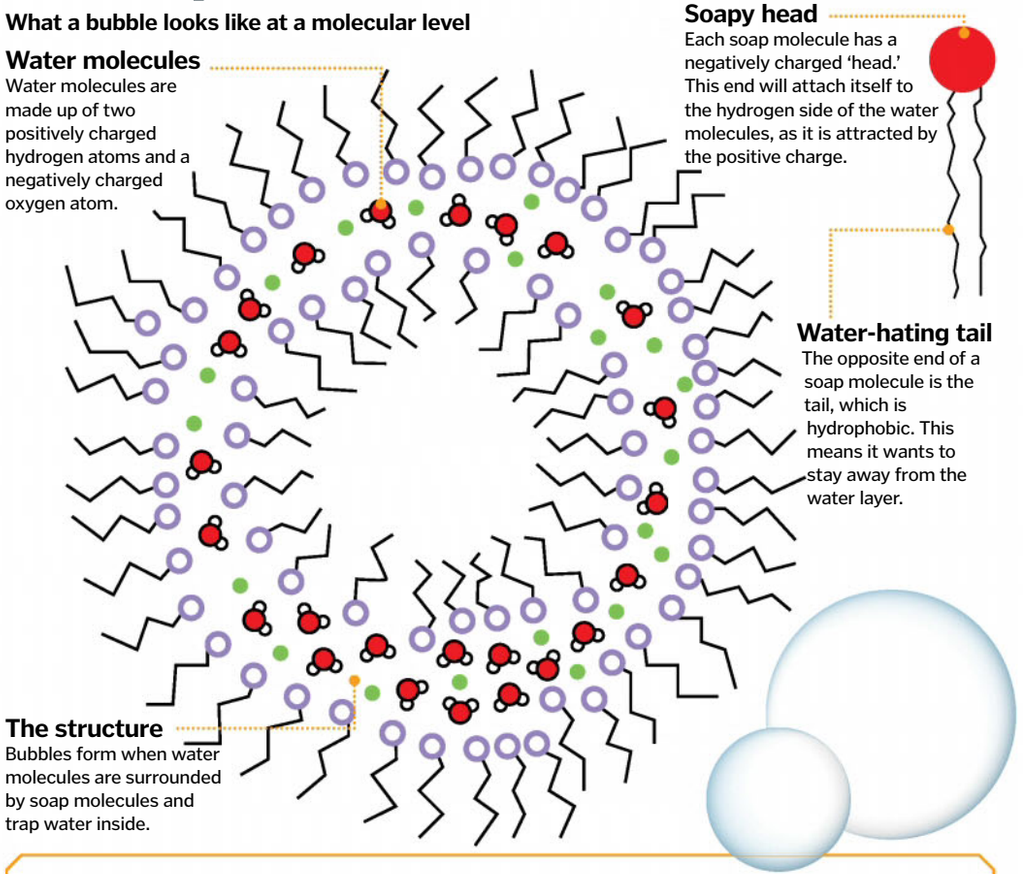
They might only come in tiny bottles but bubble mixtures can create a whole lot of fun. The contents will often be items you find in your kitchen, like washing-up liquid, water and cornstarch or glycerine. These are needed as thickening agents and glycerine also forms hydrogen bonds with the water to slow its evaporation. In order to create the bubble, dip the wand into the mixture, making sure there is a thin film over the loop. Blow slowly but firmly in order to keep the bubble expanding without bursting it through too much pressure. Once you are happy with the size of the bubble, stop blowing and rotate the wand up and around the bubble, closing it off. Without that action, the air will just escape like air from an untied balloon.



Blowing bubbles requires control

Close-up of a bubble

What a bubble looks like at a molecular level



Why a sphere?
A sphere takes the least amount of effort to form of any three-dimensional shape by far.

Going pop
It will burst if the water evaporates and there's nothing for the soap to cling onto.

Little and large
A small bubble can attach onto the other one, but would wrap around it, forming a 120-degree wall.

Two's company
A second bubble of the same size will create a flat wall when they come into contact with each other.

KEY DATES
YO-YO HISTORY

500 BCE
First historical mention of the yo-yo as Ancient Greek toys made of terracotta, bronze or wood.

1791 CE
Louis XVII and George IV are shown playing with yo-yos as children, making them the aristocracy's must-have toy.

1928
Donald Duncan buys a patent from Pedro Flores, a Filipino man who brought the yo-yo from his homeland.

1965
Duncan loses his copyright of the word yo-yo, so anyone can now call their toy a yo-yo.

1980
The ball-bearing weighted yo-yo is invented by Michael Caffrey, meaning it can now 'sleep' for longer.

DID YOU KNOW? *Echo was a mythological Greek nymph who was cursed, so she could only repeat what others had said*

The physics behind yo-yos

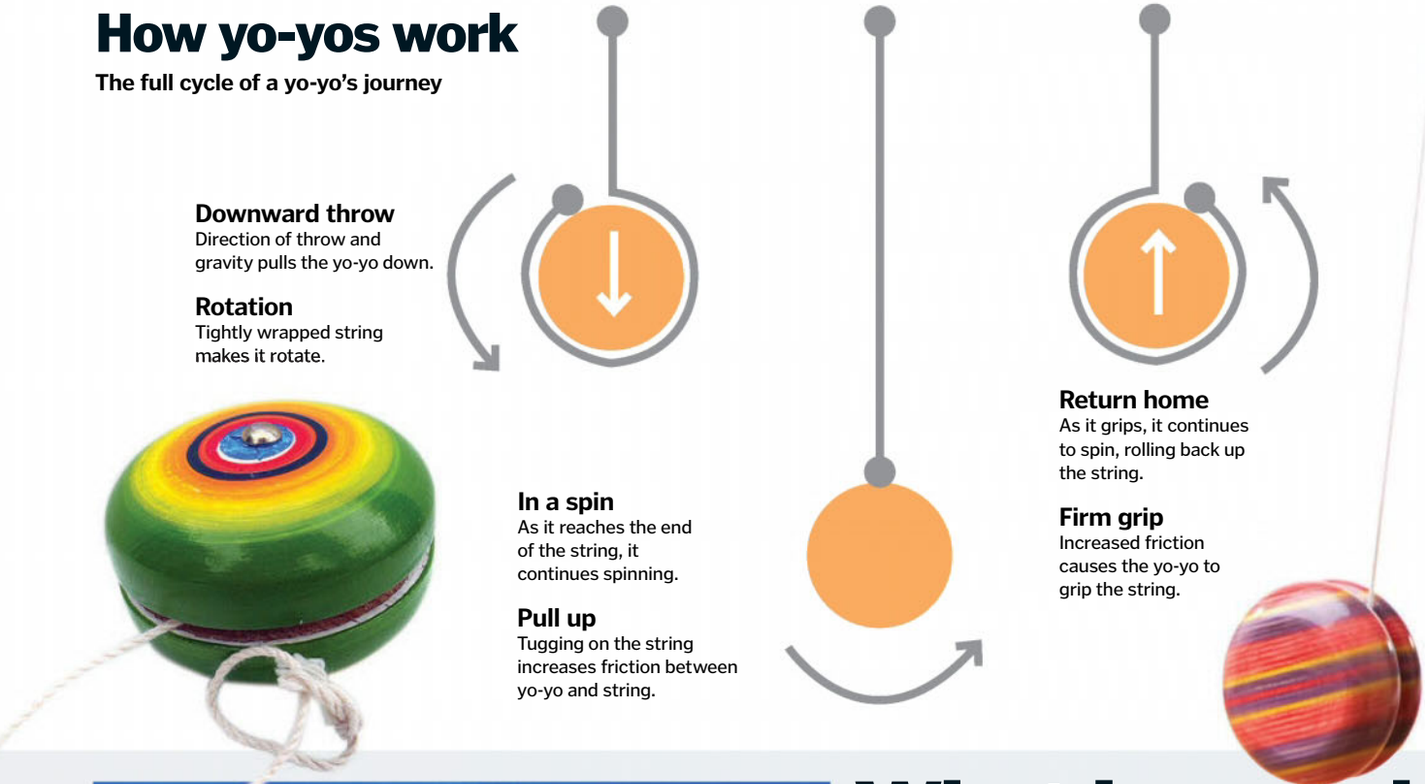
How we are able to 'sleep' and 'walk the dog' at the same time

The first part of how a yo-yo works is fairly easy to explain. A string is looped around the axle of a wheel and then wound around, making it look like a cotton reel. As you throw it out of your hand, it drops downward because of gravity and starts to spin as the string unravels around it.

But when it gets down to the bottom, gravity can't do any more work, but it continues to spin because of rotational energy. This is called 'sleeping.' A swift pull on the string increases the friction between the yo-yo and string. This makes it bite on the string and the rotations make the yo-yo wrap itself back up the string and climb back up.

How yo-yos work

The full cycle of a yo-yo's journey



Downward throw
Direction of throw and gravity pulls the yo-yo down.

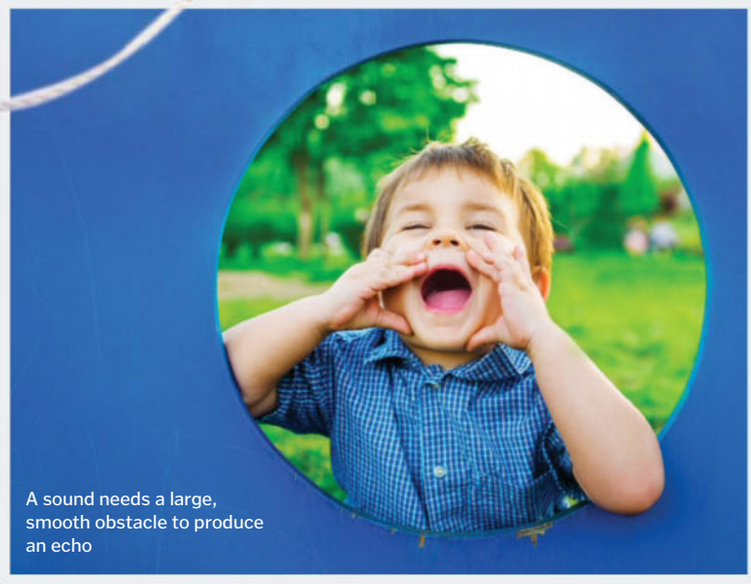
Rotation
Tightly wrapped string makes it rotate.

In a spin
As it reaches the end of the string, it continues spinning.

Pull up
Tugging on the string increases friction between yo-yo and string.

Return home
As it grips, it continues to spin, rolling back up the string.

Firm grip
Increased friction causes the yo-yo to grip the string.



A sound needs a large, smooth obstacle to produce an echo

What is an echo?

Find out how sounds return to our ears

We have all stood in a tunnel or cave and shouted out the word 'echo', but how and why does the sound of our voice keep bouncing around the space and return to our own ears?

It's all to do with reflections. When we speak, the vibrations that come from our throat move out in waves, which can be reflected by an obstacle. If you stand facing a wall and say something, you don't hear an echo because the original sound is still in your ear, as sound hovers around your ear for 0.1 seconds. Due to the speed of sound moving at 340 metres (1,115 feet) per second, that means the sound would have to travel over 34 metres (111.5 feet) in total to return to your ear after the original sound had died away, allowing you to hear the echo. The best surfaces are large and smooth to allow the sound to return to your ear.

ASK AN ASTRONAUT

Ever wanted to know exactly what it's like to be in space? Real-life astronauts reveal all...

If you were to take a look at a list of what a child wants to be when they grow up, an astronaut would place highly on nearly every one. The exhilaration of launching into space and looking down at Earth must be an experience of such magnitude that only those who have done so can describe it. So who better to ask than the people who have actually been there? Over the next few pages, you'll learn about the experiences of four NASA astronauts who reveal what it's like to live, eat and breathe in space.

The International Space Station (ISS) became operational on 2 November 2000 and has been used as an orbiting station and space laboratory ever since. It is currently joined in space by China's Tiangong station, which was launched in 2011. Space stations of yesteryear were used for military purposes – the Soviet Salyut program, for example, was in orbit during the Cold War. Nowadays however, space stations are strictly for scientific use, as astronauts and cosmonauts conduct experiments to see how the human body and man-made technology can last and hopefully flourish in this testing environment.

The ISS is the biggest object ever flown in space and travels at an average speed of 27,700 kilometres (17,212 miles) per hour, which allows it to orbit the planet 16 times a day. It's so fast that the crew see a sunrise and sunset every 45 minutes while on board. Astronauts spend their days on the space station carrying out experiments and doing tasks while their health and condition is monitored to see and analyse exactly how the human body reacts to a weightless environment.

Speaking to NASA astronauts past and present, we'll look in to how they pass the time in space, how you eat, sleep and drink in microgravity, and ultimately, how they are paving the way for future space travel. Let us go boldly where only astronauts have been before... ▶

INTERVIEWEE BIO

NAME: Rick Mastracchio
ROLE: Mission specialist
YEARS SERVED: 1990-present
GREATEST ACHIEVEMENT: Spacewalking to repair the ISS
FOOD MOST CRAVED: Homemade pasta

INTERVIEWEE BIO

NAME: Ron Garan
ROLE: Pilot and mission specialist
YEARS SERVED: 2000-present
GREATEST ACHIEVEMENT: Fulfilling the lifelong dream he had since he was a child
FOOD MOST CRAVED: Pizza

INTERVIEWEE BIO

NAME: Clayton Anderson
ROLE: Flight engineer and science officer
YEARS SERVED: 1983-2013
GREATEST ACHIEVEMENT: The first and only astronaut ever selected from Nebraska
FOOD MOST CRAVED: Medium rare T-bone steak

INTERVIEWEE BIO

NAME: Andy Thomas
ROLE: Payload commander and flight engineer
YEARS SERVED: 1992-2014
GREATEST ACHIEVEMENT: Time spent on the Mir space station
FOOD MOST CRAVED: Fresh fruit

5 TOP FACTS
NASA ASTRONAUT SELECTION

1 Vision
Every astronaut must be physically fit. However, astronauts don't have to have perfect vision as long as it is possible to correct to 20/20 visual acuity.

2 Blood pressure
Resting blood pressure must be below 140/90 mm Hg. Being under this level is believed to be the requirement for undertaking arduous tasks such as spacewalks.

3 Height
The potential astronaut must also be of a height between 157cm (5.2ft) and 190.5cm (6.3ft). This is to ensure they can properly utilise the space station and all its features.

4 Education
Every candidate must have a degree in engineering, science or mathematics along with at least three years' experience or over 1,000 hours of jet pilot training.

5 Experience
However, if you have less professional or flying experience, a masters or doctorate is acceptable. With an MA you will only need two years of experience – with a doctorate; none.

DID YOU KNOW? *The ISS treadmill was named the Colbert after comedian Stephen Colbert took an interest in the station*

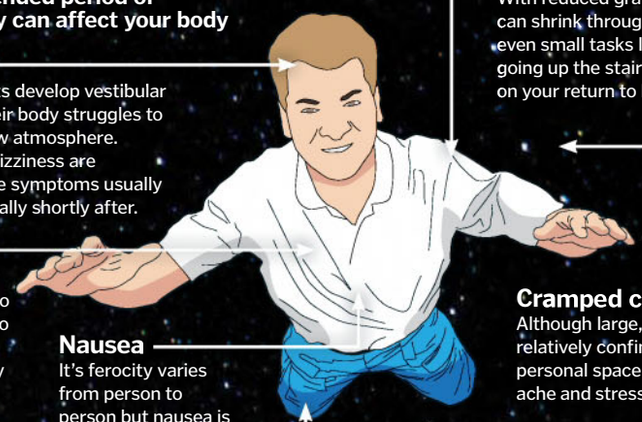
Astronaut training

How to prepare for a six-month stay in space

The training begins with the candidate assigned to the Johnson Space Center for a two-year training programme. This will include military water survival with timed lengths and treading water in flight suits. The astronauts are also exposed to microgravity in a jet that performs parabolic manoeuvres, resulting in 20 seconds of weightlessness. They can do this up to 40 times a day to get used to the sensation. There will also be tests to see how they fare in high and low atmospheric pressures as well as the all-time classic: the personal interview. The acceptance rate is only 0.5 per cent.

Effects of living in space

How an extended period of microgravity can affect your body



Balance
Some astronauts develop vestibular problems as their body struggles to adapt to the new atmosphere. Complaints of dizziness are common but the symptoms usually disappear naturally shortly after.

Heart
Without gravity your heart has to work a lot less to pump blood around the body so your cardio health can depreciate slightly. This is why cardio exercise is so important.

Nausea
It's ferocity varies from person to person but nausea is a common symptom as the astronaut gets used to a weightless environment.

Muscle mass
With reduced gravity, your muscles can shrink through lack of activity and even small tasks like walking and going up the stairs can be strenuous on your return to Earth.

Cramped conditions
Although large, the ISS is still relatively confined so a lack of personal space can cause muscle ache and stress-related disorders.

Aches and pains
Your body works much less up in space so even with two hours of exercise a day, you lack physical strength and it can take weeks to fully recover.

What is lift-off like?

The sensation of being launched into space explained

With the aid of modern technology, journeys to the ISS can now take as little as six hours, which is much more rapid than the initial 50-hour shuttle journey. The astronauts reveal what it's like...

Rick Mastracchio
"You're being tossed around quite a bit so you're strapped into your seat to keep you safe. It's always very exciting."

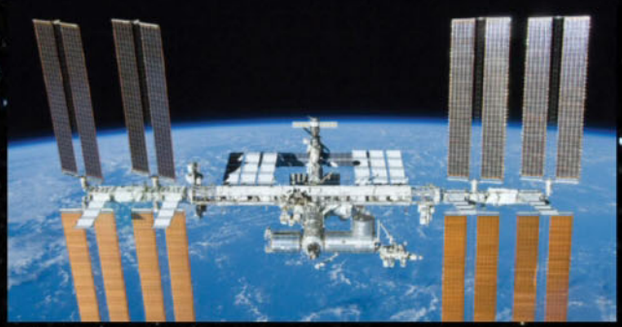
Andy Thomas
"It's quite an extraordinary experience to go from zero to 28,000km/h (17,400mph) in just eight and a half minutes. It's quite a rush."

Clayton Anderson
"The experience of a lifetime; the greatest roller-coaster ride even known to humans!"

Ron Garan

"It's not a gradual process; it is very violent and abrupt. You go from 3 g, which feels like an elephant sitting on your chest, to instant weightlessness."

The Russian Soyuz TMA-M spacecraft has replaced the Space Shuttle as the transport system from Earth to the ISS. It holds the record for the fastest ascent, a speedy six hours!



What are the first things you do on the ISS?

Andy Thomas
"The protocol for us was to carry emergency spacesuits into the space station in case we needed to leave in a hurry. That's the official mark of transition from shuttle to station. Then, of course, you bring your personal items on board and set up your quarters as you prepare for the duration of your stay."

Ron Garan
"I was being welcomed to a new home. It was an extremely human experience."

Clayton Anderson
"Marvel at where you are and that you got there safely. I was 'living the dream.'"

Rick Mastracchio
"The first thing you do is a meet and greet and then have a conference with Houston and Moscow. This is followed by a safety briefing so you know where all the emergency equipment is and ensure that everyone understands their role."

"The crew will live a day that will be based around conducting experiments and structural work"

Daily life

An everyday routine in space

Being an astronaut may not be as different to normal life as you think. When on the ISS, the crew will use GMT (Greenwich Mean Time) as their clock and live a day that will be based around conducting experiments and structural work, as well as leaving time for socialising, meals and calling home. The ISS is a sizeable craft but it is still a confined space. You have your own quarters while the main living space is shared.

Being in space for months at a time would make anyone miss their family. To help alleviate the homesickness, the astronauts are able to call their loved ones whenever they want using an IP (Internet Protocol) phone system. It works by using a communications satellite to send the space station's signal back down to Earth. Using the technology available, any phone on Earth can be called. It's really not as difficult as you may think. Email is also available on the station and video calls can be held once a week.

Without the effects of gravity, your body works less, so muscle mass can reduce drastically when the body is in space for an extended period of time. As a result, regular exercise is key. The machines used in space differ to your typical Earth gym. NASA use specialised treadmills and bikes for cardio and a specially adapted weight machine for resistance training.

The ARED (Advanced Resistive Exercise Device) aids muscular strength by providing workouts for all the key muscle groups, such as squats and deadlifts. The treadmill is known as the Colbert (Combined Operational Load-Bearing External Resistance Treadmill) or rather more simply T-2 and has some differences to an Earthbound running machine. The user is held in place by elastic straps and a system has been put in place so the machine's vibrations don't affect the sensitive experiments on the station. This is done by placing the treadmill on springs and dampeners to lessen the shock.

"We exercise on a daily basis", explains Rick Mastracchio of the astronauts' space exercise regiment. "We spend about an hour a day doing cardiovascular exercise on a treadmill and an exercise bike. We will then spend another hour weightlifting using air pressure as resistance."

Sleeping

"[You sleep] Vertically in a sleeping bag strapped to the wall. I averaged seven hours and 20 minutes of sleep every night! Probably better than I get here on Earth."

Mealtimes

"It's basically like camping food. Most of it is dehydrated or irradiated. The Russians tend to use cans and their food is a lot more like real food."

Brush teeth

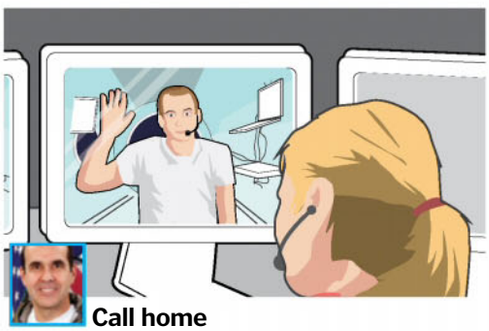
"You brush your teeth similar to how you do on Earth but there isn't a sink, so you spit onto a tissue and throw that away."

Shower/wash

"You wet a face cloth with soap and water and then wipe yourself down. We used a non-rinse shampoo, which wasn't that bad. It's not perfect, but it works."

Exercise

"The heart doesn't need to work nearly as hard in zero gravity to pump the blood. If you don't exercise, it can weaken. The solution is a daily exercise regime with cardio and resistance exercises."



Call home

"We have a phone that can make calls to Earth. It's available most of the time so we call home and speak to friends and family. We also have a video conference once a week."

Get dressed

"Space is where impossible things are easy and the easy things are difficult. You're able to float with incredible views of the Earth but the easy things like getting dressed are much more difficult!"

Relax

"It's a very busy place but we try and get together when we can for a meal. We also have films on laptop computers and you can look back at Earth through the window for hours on end. Every time it's breathtaking."

THE STATS
ISS STATS

2,500m² SOLAR PANEL SURFACE AREA

214 NUMBER OF PEOPLE TO VISIT THE ISS

52 COMPUTERS CONTROL THE ISS SYSTEMS

3rd BRIGHTEST OBJECT IN THE SKY

PREDICTED FINAL YEAR OF ISS OPERATION **2020**

MINUTES TAKEN TO CIRCLE THE EARTH **90**

DID YOU KNOW? *An astronaut's suit costs approximately $2 million (£1.2 million) to make. That's an expensive outfit!*

Spacewalking

Describing the feeling of being suspended in space

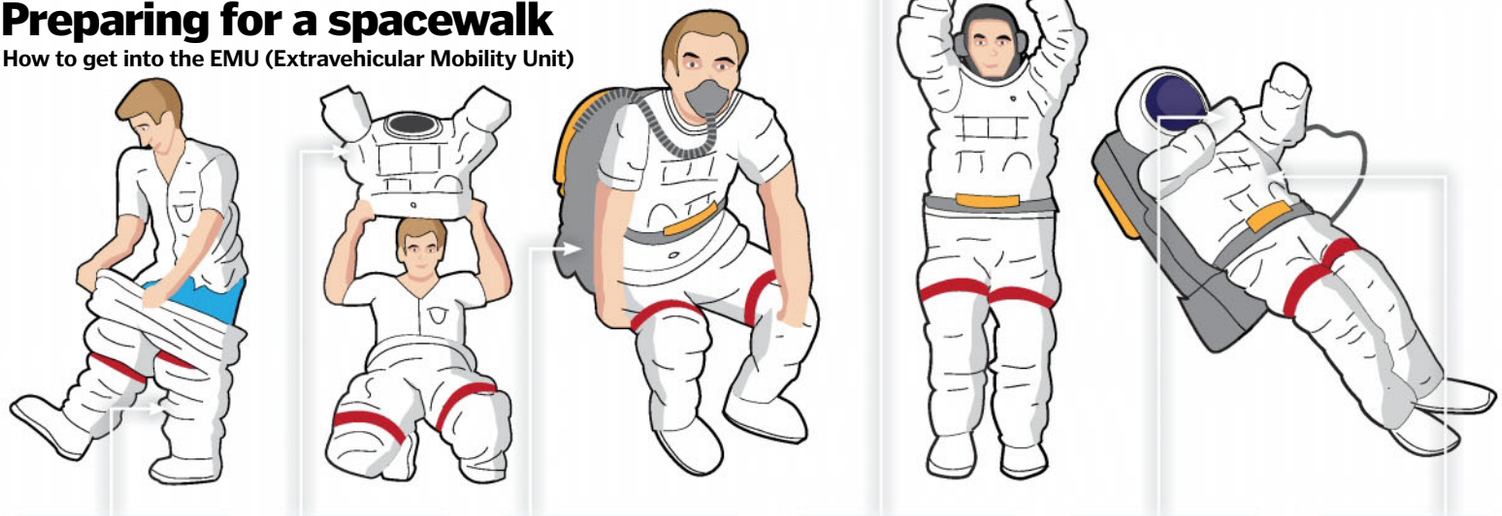
When speaking to the four astronauts, each one was particularly proud of the opportunities they had to spacewalk. "Spacewalking is the goal of every astronaut. Going up to space is incredible, but a spacewalk takes it that much further," says Rick Mastracchio of his experience leaving the spacecraft. "When you're up there in the suit you have a great sense of freedom."

As well as the breathtaking sights of Earth and the vast emptiness of space, the spacewalk also has a very important function in that it's essential to the maintenance and repair of the station. Andy Thomas reveals that the task is not as easy as it may sound. "It's very hard work and is very strenuous," he admits.

"The suit is massive and it is pressurised so flexing any of your joints is very difficult. After a few hours your fatigue builds up massively so at the end you're very tired." The walks are so important that there is little time to marvel at the scenery. Clayton Anderson described the experience as "a majestic but deadly environment. Mistakes are your enemy and the pressure to succeed without making even one is intense. It is truly more of a mental than physical exercise." Integral and exhilarating, spacewalking remains one of the peaks of the ISS experience. Ron Garan sums up the view as "the backdrop of infinity."

Preparing for a spacewalk

How to get into the EMU (Extravehicular Mobility Unit)



Boots
Specifically designed for spacewalking, the boots protect against the harsh environment of space and contain clips that can be used to attach to a railing if the task requires both hands.

Top half
This is made out of fibreglass and contains the suit's life-support and control systems. A water pouch is also located in the upper torso .

Electronic apparatus
An electronic display and several control gauges show the condition of the astronaut's life-support systems. For extended treks, cereal bars can be carried within reach of the astronaut's mouth.

Helmet
A gold-coated visor protects from the Sun's harmful rays, extreme temperatures and possible impacts. Small vents are used for the intake of oxygen and output of carbon dioxide.

Gloves
These gloves contain internal heaters to keep an astronaut's fingers toasty during long excursions. The thick, rubber fingertips mean they still have a good sense of touch.

Ready
Once every piece of clothing is on and it is all interlocked, the astronaut is ready to step outside and begin the EVA (Extravehicular Activity).

ABOVE Rick Mastracchio investigating how fluids act in microgravity on the ISS. The results of this experiment could benefit future liquid delivery and containment on the station and other spacecraft

How tests in space can improve life on Earth

The most integral projects undertaken on the ISS are the scientific experiments. First, microgravity has a big affect on organisms and has been observed to alter both genes and tissue. There are also increased amounts of radiation and variable temperatures on space stations so tests are carried out to see how not only humans but also man-made machinery can function and even adapt to space-like conditions.

The experiments can greatly benefit life on Earth, as Ron Garan explained that new capsulation technology was tested on the ISS to help treat cancer and other research is helping to develop a vaccine for Salmonella. One of the most recent developments has been the proposed creation of 'space salad.' Current space food does have some variation but for extended stays, growing our own foodstuff is essential. Still in the planning stage, further experiments are being carried out using 'plant pillows' instead of soil.

"The crew see a sunrise and sunset every 45 minutes while on board the ISS"

Inside the ISS

A look inside Destiny, the US section of the ISS

Both a laboratory and a spaceport, the International Space Station has orbited Earth over 80,000 times and travelled an equivalent of 22 round trips to the Sun. Larger than a six-bedroom house, the ISS is made up of many different segments, from a gymnasium to the various astronaut quarters. The first part of the station launched was the Russian-built Zarya in 1998, which took cargo, fuel and storage space up to a low Earth orbit. This began the construction and opening of the station as we know it today.

Space tourism

Could we be taking trips into space in the near future?

With astronauts evidently flourishing on the ISS and other space stations, it's only a matter of time before Joe Public experiences space life, right? The frontrunner in this business is Virgin Galactic, which is pioneering public space flights, but other large firms are also registering varying degrees of interest. Several businessmen have paid their way into space by gaining access to the ISS in the early-21st century but these instances are very few and far between. However, if a five-star hotel is what you're looking for, this is still a long way away, so don't be counting on intergalactic room service anytime soon.

Laboratory module
This area is where all experiments are conducted. To help with testing, the temperature can be manually altered and there is a supply of hot water.

Crew quarters
Your sleeping bag is attached to a wall so you can't float off mid-slumber, and is around the size of a phone booth.

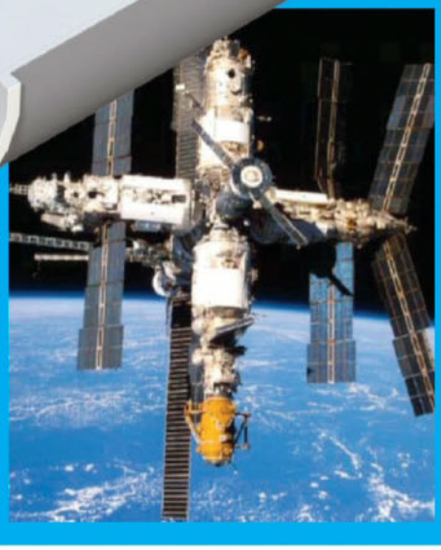
To Columbus
This is only one of the many sections of the ISS. This direction takes you to Columbus, the European section of the space station.

Hub of Destiny
The US research laboratory is known as Destiny and was the first research area installed on the ISS.

To Kibo
This way takes you to Japan's space lab Kibo, which means 'hope' in Japanese.

Mir space station

Facts on the now-defunct Russian equivalent of the ISS



Before the ISS there was Mir, the pinnacle of the Soviet space program. Outlasting the Soviet Union itself (it was de-orbited in 2001), Mir functioned for 15 years after its original launch in 1986. As well as conducting experiments like other stations, Mir was also mooted as a possible tourist destination. Although millions were invested, the tourism idea was quickly shelved. Probably a good thing too, as the Mir began to experience safety concerns later in its life. In 1997, a fire broke out when a life-support system malfunctioned. Although it was eventually extinguished, this proved to be the beginning of the end of the Mir and it was re-entered into the atmosphere in a controlled de-orbiting operation. The majority of the station burned up as it came back into Earth's atmosphere but large chunks still had to be removed from its fall into the South Pacific.

KEY DATES
HISTORY OF THE ISS

1984
US President Ronald Reagan outlines the initial plans to build an international space station.

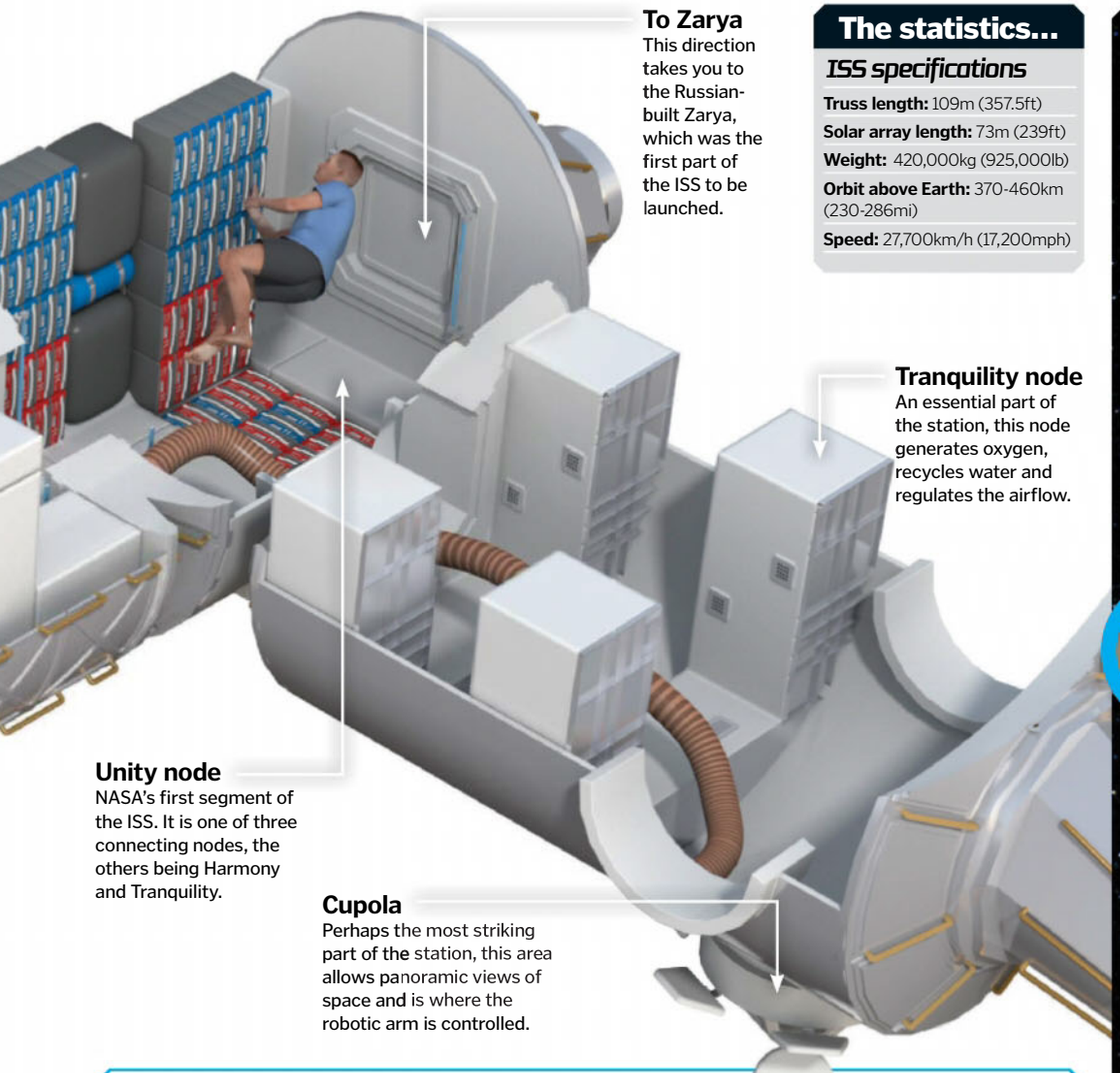
1998
The first part of the station is launched, a Russian rocket known as Zarya.

2000
American Bill Shepherd and Russians Yuri Gidzenko and Sergei Krikalev become the first people to live on the station. They stay for several months.

2008
The first European laboratory becomes operational. A Japanese lab opens a month later.

2010
The ISS celebrates its tenth anniversary of human occupation. 202 people have visited the station by this point.

DID YOU KNOW? *NASA is aiming to land on an asteroid by 2025 and get astronauts to Mars perhaps even earlier!*



To Zarya
This direction takes you to the Russian-built Zarya, which was the first part of the ISS to be launched.

Tranquility node
An essential part of the station, this node generates oxygen, recycles water and regulates the airflow.

Unity node
NASA's first segment of the ISS. It is one of three connecting nodes, the others being Harmony and Tranquility.

Cupola
Perhaps the most striking part of the station, this area allows panoramic views of space and is where the robotic arm is controlled.

The statistics...

ISS specifications

Truss length: 109m (357.5ft)
Solar array length: 73m (239ft)
Weight: 420,000kg (925,000lb)
Orbit above Earth: 370-460km (230-286mi)
Speed: 27,700km/h (17,200mph)

Quick-fire questions

What's the longest you've been in space at any one time?

Rick Mastracchio: "Just returned from a 188-day mission on the ISS."
Andy Thomas: A 20-week mission on MIR.
Clayton Anderson: 151 days, 18 hours, 23 minutes and 14 seconds.
Ron Garan: Five and a half months on the ISS.

What were some of the best views of Earth from space?

Rick Mastracchio: I always thought the Caribbean was incredibly beautiful. Lightning storms were also amazing to watch. You can see the flashes in the storms that seemed to engulf half of the African and Australian continents.

Clayton Anderson: "Variations in landmasses, cloud cover and vegetation are the most striking. It is difficult to see anything specific, except dams and the 'blobs' that are cities."

Ron Garan: "On my first mission, I would ask where we were, but after being in space for six months on my second mission it felt like my back yard and I knew where nearly everything was on Earth!"

What are you allowed to take up with you? Any essentials or luxuries you can't be without?

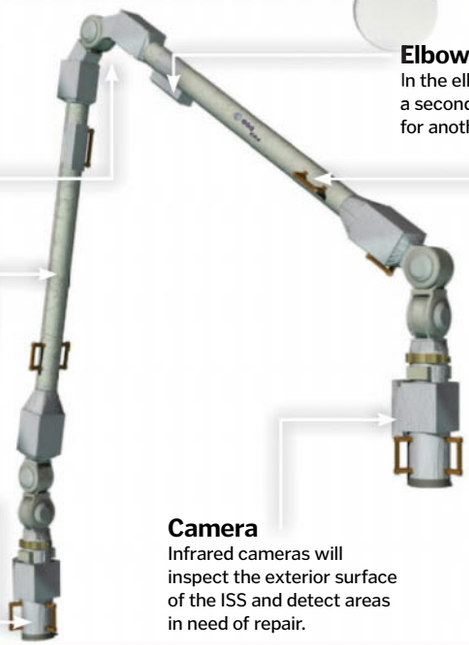
Andy Thomas "DVDs, CDs and personal mementos. Clothing and personal hygiene products are provided for you and I always take a spare pair of glasses as it is easy to lose them up there!"

Rick Mastracchio: We have cargo vehicles that show up on the Space Station that can carry personal items for the crew, like food or family photos. We had five come up in the six months we were up there. You can take small mementos like jewellery but nothing big. You're allowed one-and-half pounds' [0.7 kilograms] worth of personal items.

Clayton Anderson: You can take small things that weigh a minimal amount. Weight is bad in space flight. I took family pictures and mementos that I could return and give to special friends and family.

The ISS' robotic arms

The Space Station's next mechanical limb



Elbow
In the elbow of the mechanism is a second camera and lighting unit for another angle of imagery.

Materials
The limb is strong and flexible and is constructed out of carbon fibre and aluminium as well as beta cloth blankets for thermal protection.

Limb
This is the robotic arm that the ESA (European Space Agency) plan to install on the Russian segment of the ISS to help assemble and repair it.

End effector
This part of the arm contains power, data and video signals and is the hub of the arm's communications back to the ISS.

Handrail
The extra vehicular activity handrail can be used as support to a by a spacewalking astronaut who is repairing the outside of the station.

Camera
Infrared cameras will inspect the exterior surface of the ISS and detect areas in need of repair.

"If you were to scoop a teaspoon full of material from this object's surface, it would weigh in at 1 billion tons"

Mysterious magnetic stars

Meet a star with a magnetic field that's quadrillions of times more powerful than Earth's

There are plenty of exotic objects in the universe and many might agree that the magnetar fits neatly into this category. Magnetars are exactly what their name infers – they are stars with a monstrous magnetic field, quadrillions of times stronger than any magnet humans can build. It's said the magnetar is so powerful that if you placed one at a distance halfway to the Moon, it would have no trouble stripping information from all the credit cards in the world. But what makes them so powerful?

Magnetars are rapidly spinning neutron stars, made from the collapse of a massive star during a supernova explosion. However, the full details of how they are made is still a mystery that continues to baffle astronomers to this day. It's said that if you were to scoop a teaspoon full of material from this object's surface, it would weigh in at 1 billion tons. What's more, a magnetar can also shift its bulk at alarming speeds, completing one pirouette in no more than ten seconds. It's also capable of spitting out very strong bursts of X-rays and gamma rays – the most penetrative of radiation – which is truly characteristic of the magnetar.

These bizarre objects don't live for very long in astronomical terms. It's believed they start to feel their age and wind down after about 10,000 years and, as a result, astronomers estimate there are at least 30 million inactive magnetars in the Milky Way galaxy compared to a very much alive and confirmed 23.

Dynamo power!
It's thought an extremely turbulent, yet dense, fluid provides the magnetar with its incredibly powerful magnetic field.

An explosive formation
Magnetars are made when, in a supernova, a star collapses to make a neutron star with its magnetic field increasing dramatically in strength.

A dying breed
To date, just over 20 active magnetars have been found. Estimates suggest there are likely to be over 30 million 'dead' magnetars in the Milky Way alone.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

The magnetar mystery could have been solved

www.howitworksdaily.com

DID YOU KNOW? *Magnetars often have 'starquakes' on their surfaces, detected from Earth in the form of gamma rays!*

Anatomy of the magnetar

The astronomical make-up the universe's strongest magnets

Lethal magnetic field

It's said that a magnetar's magnetic field is so powerful that even at a distance of 1,000km (620mi) it would still be bad news for life, distorting molecules.

Heavyweight champion

They might only have a diameter of 16km (10mi), but magnetars are much heavier than our Sun.

Living a short life

The powerful magnetic fields these rapidly spinning stars exude are very short-lived. After about 10,000 years the magnetar becomes increasingly powerless.

How were magnetars discovered?

In March 1979, after dropping satellites onto the surface of Venus, two Soviet spacecraft were sent drifting though the Solar System when they were all of a sudden blasted by an immense burst of gamma radiation, causing the readings on both probes to skyrocket from 100 counts per second on to over 200,000 counts per second. The numbers jumped in almost an instant, or mere fractions of a second.

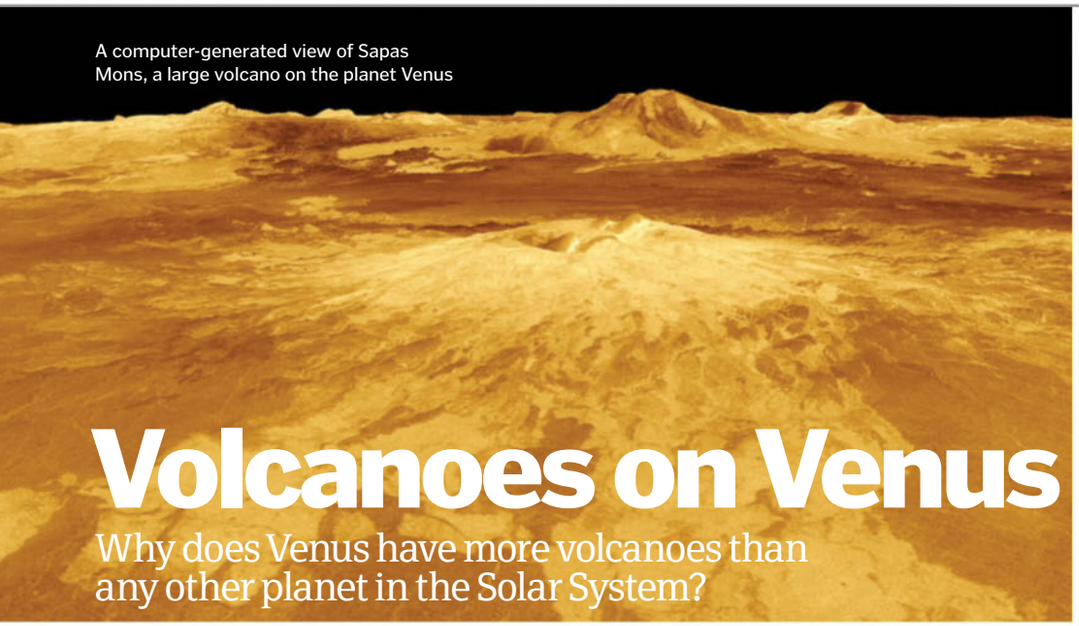
Amazed and somewhat bemused by the finding, scientists followed up on the mysterious blast that saturated the likes of NASA's Helios 2 probe, the Pioneer Orbiter around Venus and, mere seconds later, many satellites orbiting our own planet. The radiation seemed to seep in everywhere, which made it easier for astronomers to work out where it was coming from. Narrowing the direction down, they figured out the radiation was coming from a magnetar made by a star that had gone supernova around 3000 BCE.

They can spin fast or slow

We know magnetars spin incredibly fast, but what's more interesting is that they're also capable of putting on the brakes, so to speak, and slowing themselves down. It's an interesting observation but it's also one that can't be easily explained by our existing theories of physics, making the magnetar even more mysterious.

That's not to say that astronomers haven't had some intelligent guesses as to what could be causing the behaviour they refer to as the "anti-glitch issue." They speculate there are pockets of fluid inside the star that's rotating faster and faster until it's sloshing around much faster than the stellar crust on the surface. Of course, this theory has not been proven yet, but scientists are beginning to wonder if these disturbances cause a magnetar's crust to crack, leading to their decline.

"...as it moves across its stellar parent's surface it blocks out a portion of light..."



A computer-generated view of Sapas Mons, a large volcano on the planet Venus

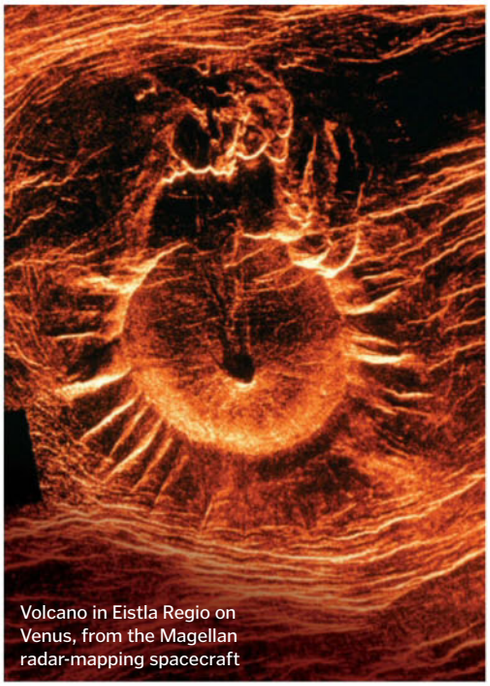
Volcanoes on Venus

Why does Venus have more volcanoes than any other planet in the Solar System?

It's incredibly hot, with a searing average temperature of 460 degrees Celsius (860 degrees Fahrenheit) - much muggier than deserts on Earth. Its atmosphere is thick with choking carbon dioxide, laced with poisonous sulphuric acid clouds that hang above a parched landscape. This is the setting of the second planet from the Sun, Venus – also known as Earth's evil twin – and it's taken some of our comparatively tranquil planet's characteristics to the absolute extreme.

In a world where you would be cooked, crushed and choked within a few seconds, Venus has its dominating network of volcanoes to thank for its hellish state – over 1,600 volcanoes that have been so active in Venus' past have angrily and unpredictably erupted to renew the planet's surface with plains of lava. From high peaks to volcanoes built almost entirely from fluid lava flows and the very unusual volcanic pancake domes, Venus is a geological paradise. But how did they get here in the first place and why are there so many?

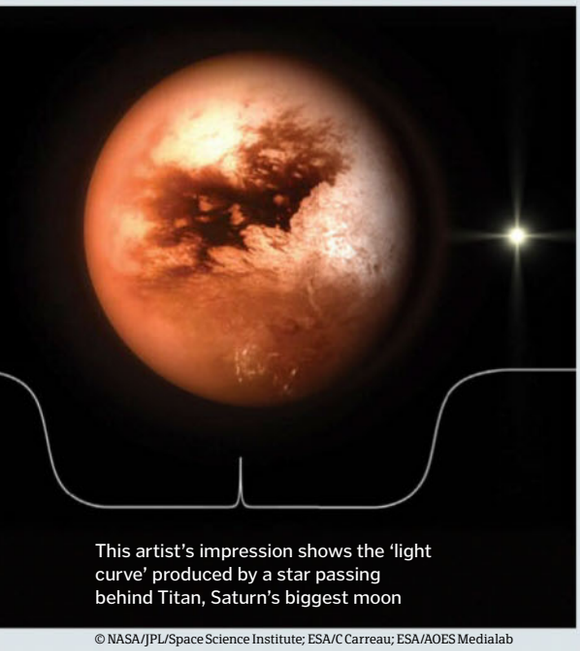
Venus' anger under the planet's crust made the volcanoes so many probes have detected through its thick cloud layer. Magma works its way to the surface, making some of these volcanoes bigger and bigger. Why the planet has so many is all down to the lack of the wind and water erosion witnessed on Earth – without these, they're never destroyed.



Volcano in Eistla Regio on Venus, from the Magellan radar-mapping spacecraft

Venus' king of volcanoes

Out of the many volcanoes found on Venus' hellish surface, Maat Mons in the highest of them all, reaching a tall eight kilometres (five miles) toward the thick Venusian skies. Whether Venus is still volcanically active is still something that cannot be decided among the scientific community, as present-day eruptions of this monstrous peak are yet to be confirmed.



This artist's impression shows the 'light curve' produced by a star passing behind Titan, Saturn's biggest moon

How light curves work

Astronomers have an ingenious way to spot planets orbiting distant stars

When it comes to searching for alien worlds, the light curve is a planet hunter's best friend. The distant stars that pepper the universe throw out plenty of light toward us and a world in orbit around this star plays with this light in such a way that the astronomer is able to spot it lurking there.

A star with no planets throws out pretty much a constant intensity of light. To visualise this, imagine a straight horizontal line. Now put a planet around this star – as it moves across its stellar parent's surface it blocks out a portion of light every time it dances around it in its orbit. A slight drop in intensity means the horizontal line that you imagined earlier has dips in it every time the world swings across its star's surface. What's amazing about these light curves is that astronomers are able to find out a wealth of information about the planet and star in question. Not only are they able to work out its size, but by combining this with other planet-finding methods, they can also get an idea of the world's density and structure.

5 TOP FACTS
SPARKLY TRUTHS

Iron planets
1 Carbon worlds will still have inner cores of iron, just like Earth, around which are layers of diamond and graphite. The surface will be rich in hydrocarbons like methane.

Diamond volcanoes
2 While volcanoes down here on Earth spew up molten silicate rock when they erupt, it is possible that volcanoes on a carbon world will erupt diamond.

More carbon, the better
3 A carbon-to-oxygen ratio of 0.65 allows carbon worlds to form very close to their stars. Increase the ratio to 0.8 and these could exist further away, in the habitable zone.

Earth is carbon poor
4 Although carbon is important for life on Earth, it is uncommon compared to other materials on Earth, making up only 0.1 per cent of Earth's mass.

Dry planets
5 Carbon worlds will have little water because of the lack of oxygen, which also reacts with carbon. On a carbon planet, water would be worth more than diamond!

DID YOU KNOW? *Future space telescopes could discover carbon planets by detecting the spectral signature of carbon*

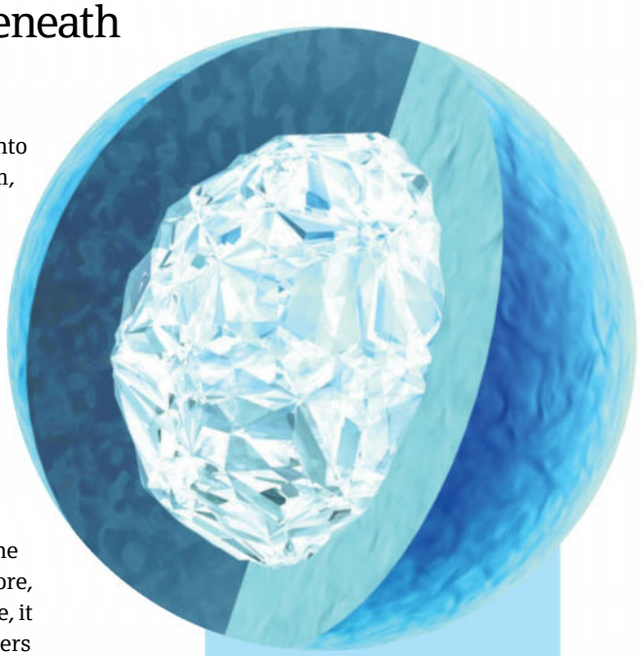
Diamond planets

Some alien worlds are a girl's best friend, for just beneath their surface is a core of solid diamond

Earth is an oxygen-rich planet; it's in the air that we breathe, the water that we drink and the silicate rock that we stand on. Imagine a planet, though, where there is hardly any oxygen but lots of carbon instead. These 'carbon planets' hold a special secret – below the surface the high pressures crush the carbon into graphite (the 'lead' in your pencil) and, even deeper, into diamond.

Astronomers have shown that planets form by condensing from disks of dust and gas around young stars. If the ratio of carbon to oxygen in these disks is higher than 0.65 then carbon-rich rocky worlds can be assembled. Life on such worlds would be difficult, if impossible, because there is so little oxygen that it's unlikely there would be much water. The atmosphere would be thick with carbon dioxide and poisonous carbon monoxide, into which towering mountains of graphite form, while below the bedrock would be as hard as diamond because that's literally what it would be.

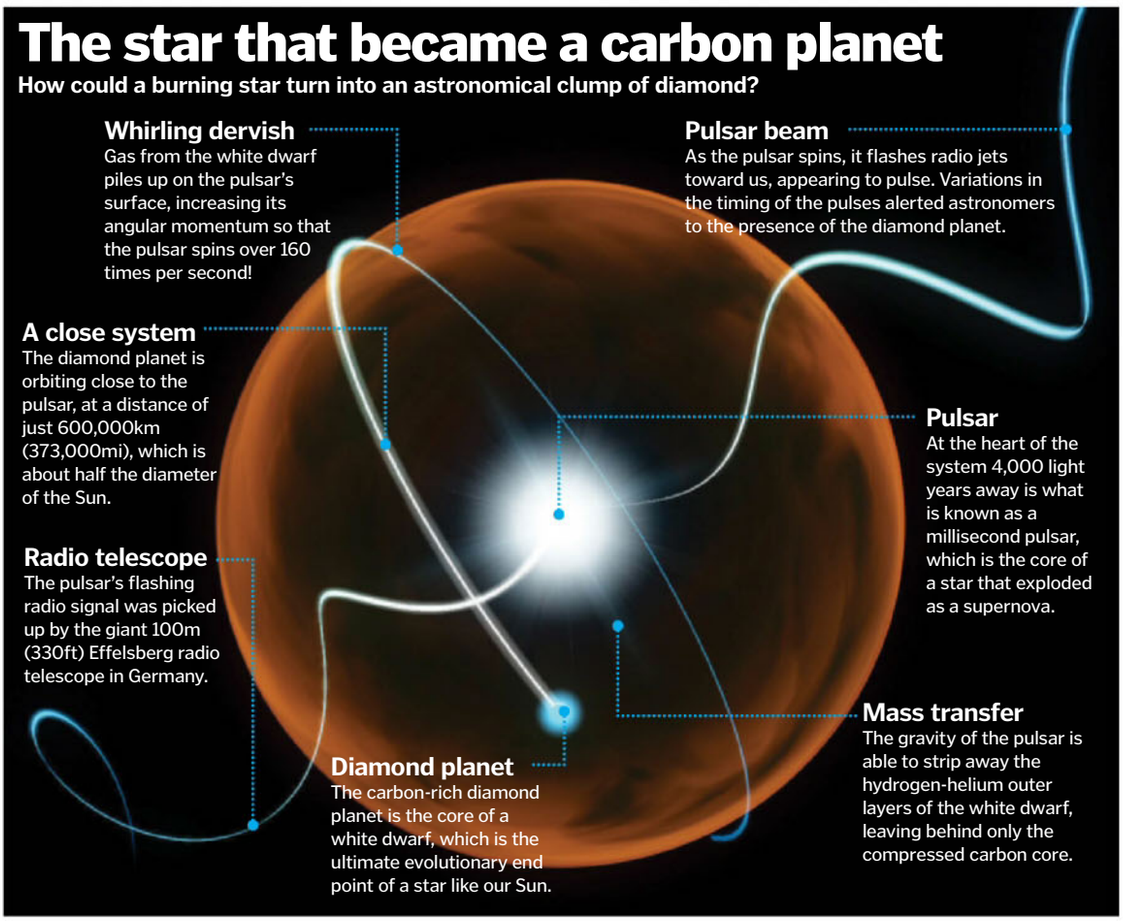
Not all diamond planets are made in the same fashion. One suspected carbon 'planet' found orbiting a pulsar – a spinning supernova remnant emitting beams of radio waves – is believed to have once been a star itself. The star grew old and died, leaving behind a white dwarf, which is about the size of Earth. This white dwarf lost its outer layers to the gravity of the pulsar, revealing the white dwarf's inner core, made of solid crystal diamond. What's more, it will outlast our Solar System and many others – this diamond really is forever!



An illustration of what the inside of a diamond planet may look like

The star that became a carbon planet

How could a burning star turn into an astronomical clump of diamond?



Whirling dervish
Gas from the white dwarf piles up on the pulsar's surface, increasing its angular momentum so that the pulsar spins over 160 times per second!

Pulsar beam
As the pulsar spins, it flashes radio jets toward us, appearing to pulse. Variations in the timing of the pulses alerted astronomers to the presence of the diamond planet.

A close system
The diamond planet is orbiting close to the pulsar, at a distance of just 600,000km (373,000mi), which is about half the diameter of the Sun.

Pulsar
At the heart of the system 4,000 light years away is what is known as a millisecond pulsar, which is the core of a star that exploded as a supernova.

Radio telescope
The pulsar's flashing radio signal was picked up by the giant 100m (330ft) Effelsberg radio telescope in Germany.

Mass transfer
The gravity of the pulsar is able to strip away the hydrogen-helium outer layers of the white dwarf, leaving behind only the compressed carbon core.

Diamond planet
The carbon-rich diamond planet is the core of a white dwarf, which is the ultimate evolutionary end point of a star like our Sun.

The mysterious case of 55 Cancri e

Discovered in 2004, the exoplanet 55 Cancri e is the closest of five worlds found to orbit the star 55 Cancri in the constellation of Cancer. It is a super-Earth with twice the diameter of our planet and over eight times the mass. Because it is seen to transit in front of its star, astronomers are able to make accurate measurements of the planet's chemical make-up. They detected no hydrogen, which is odd. Hydrogen is the most common element in the universe, but it is also the lightest, and that close to its star it will be blown away unless it is locked into a molecule such as water. Water, however, needs oxygen, but a carbon planet would have no oxygen and hence no water or hydrogen. However, it was subsequently discovered that its star has 25 percent more oxygen than carbon, implying the planets should follow suit. If that is the case, then 55 Cancri e cannot be a carbon world, leaving its exact nature still a mystery at this point.

WORLD'S FASTEST TRAINS

DISCOVER THE LEVITATING TRAINS THAT GO FASTER THAN 300MPH

THE STATS
THE SHANGHAI MAGLEV

TOP SPEED **501km/h** AVERAGE SPEED 251km/h DISTANCE 30.5km

JOURNEY TIME 7m 20s JOURNEY COST £4.90 / $8.14 (50 Yuan) FIRST RUN 2004

DID YOU KNOW? *On average, each central Japanese bullet train arrives within six seconds of its scheduled arrival*

For many of us, the daily train commute is a slow, boring necessity, but what if you could travel at a mind-bending 430 kilometres (267 miles) per hour? That is the reality for passengers travelling on the world's fastest train, the Shanghai Maglev.

High-speed trains have been around since 1964, when a line between Tokyo and Osaka in Japan was built to reach speeds of 210 kilometres (130 miles) per hour. This shortened the time it took to travel between two of Japan's largest cities dramatically, and the world's love of high-speed rail was born.

Many of the world's fastest trains today use magnetic levitation to achieve daily speeds that are over six times the British motorway limit. However, high-speed travel is possible without using magnets. Britain has plans for its second high-speed rail track, from London to Manchester and Leeds via Birmingham, called HS2. The project's technical director, Professor Andrew McNaughton, explains there are other ways to achieve super-speed:

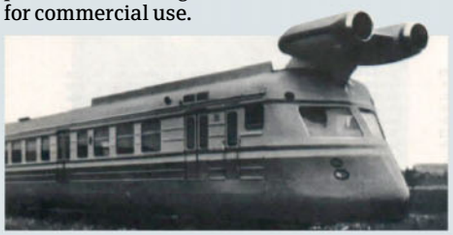
"The point of contact between the steel wheel and the steel track is only the size of your fingernail, so we are not too worried about friction, plus the energy required to levitate a train is huge", he says. "HS2 will have 100 horsepower, which is four times more than [in] normal trains. It will only stop at a few stations so won't have to slow down and speed up often at all."

The proposed HS2 train will drastically reduce the time it takes to get between the south and north parts of England by simply using a more powerful engine and fewer stops. However, even though the engine is more powerful, it doesn't actually use that much more energy. The train will use a big burst of power to get up to speed and essentially coast along after that. It will be able to reach a top speed of 360 kilometres (224 miles) per hour and have an average speed of 230 kilometres (143 miles) per hour on its cross-country journey. This will halve the time it takes to get from London to Manchester.

Whether they are suspended in the air or equipped with a monster of an engine to get them off the starting line, high-speed trains are revolutionising the way we travel.

Jet-powered trains

While magnetically driven trains seem to be the future, back in 1966, rockets were all the rage, so naturally someone decided to pop a couple onto a train to see how fast they could go. That person was New York Central Railroad engineer Don Wetzel. He was engaged in an experiment to see how fast he could make a train travel, so used two General Electric J47-19 jet engines on a Budd Rail Diesel Car train with a modified nose for extra streamlining. They named it the Black Beetle and on one run it hit a monumental 295.6 kilometres (183.7 miles) per hour. This remains the record for the fastest train ever to run in the USA, but Wetzel's idea wasn't to last. Rocket-powered trains did not become a viable alternative to steam or electric as they were expensive, difficult to source and provided unmanageable amounts of thrust for commercial use.



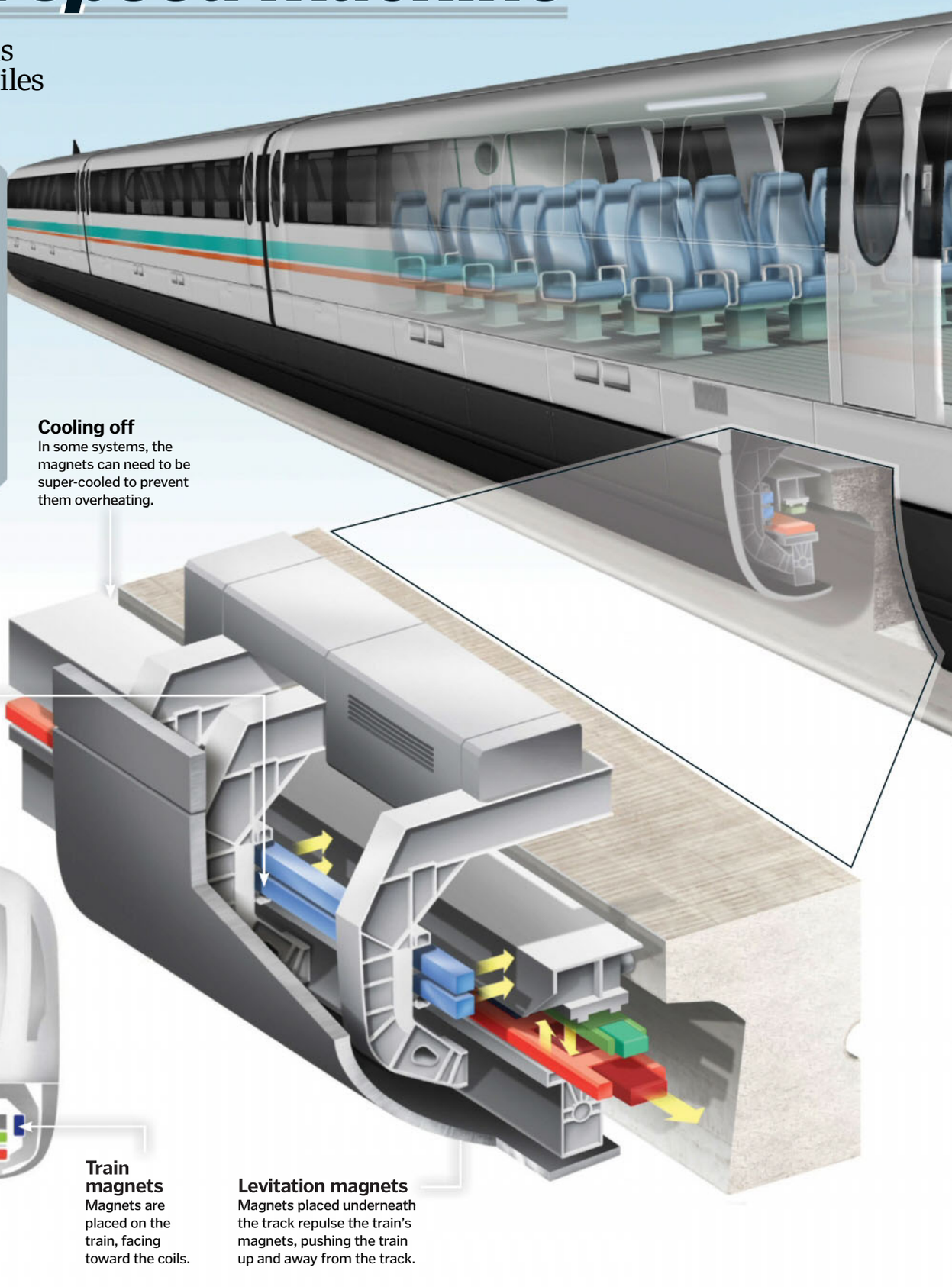
"Magnets placed underneath the track repulse the train's magnets, pushing the train up"

Inside a speed machine

How do maglev trains travel hundreds of miles per hour?

Advantages

The obvious advantage is getting to places much, much quicker. The HS2 high-speed train will halve the journey time between the London and Manchester, which will be a great boost to both cities. The Beijing to Shanghai high-speed railway cuts the journey time from nearly ten hours to five. The other huge benefit is that maglev trains don't have engines so there are fewer things that can malfunction. They are solely powered through electromagnets in the track and train and batteries inside the train.



Cooling off
In some systems, the magnets can need to be super-cooled to prevent them overheating.

Inductrack
A cheaper system uses coils of copper wire arranged in such a way as to produce a constant magnetic field and the train's motion sends a current through the coils, propelling the train upward and forward.

Defying gravity
As it is not actually touching the track any more, the train has no friction to work against so can go faster.

Train magnets
Magnets are placed on the train, facing toward the coils.

Levitation magnets
Magnets placed underneath the track repulse the train's magnets, pushing the train up and away from the track.

HEAD 2 HEAD
RAILWAY SPEEDSTERS

AGV Italo
The AGV Italo's maximum operational speed is 300km/h (186mph). Its known as the 'Ferrari of the railways' thanks to its sleek red design.

Harmony CRH380A
This Beijing to Shanghai train has clocked 486km/h (302mph) and is notable for its anti-vibration technology.

Shanghai Maglev
The daddy of all high-speed trains, it has topped 500km/h (311mph) and averages 251km/h (156mph).

DID YOU KNOW? *It is estimated that Shinkansen cut around 400 million hours each year from Japanese travelling times*

Aerodynamic shape
High-speed trains are designed with a pointed nose like an aeroplane to cut through the air.

Disadvantages
The main problem with maglev trains is that they are a closed system. This means they can only run on a specially designed rail and no other trains are able to run on their tracks. It is for this reason HS2 decided to use traditional technology for their trains so they could continue to non-high-speed destinations. They are also very expensive to build, the cost of the 30-kilometre (18-mile) Shanghai Maglev being £720 million ($1.2 billon). Keeping the magnets cool as well is a costly task, although it does save energy.

Guideways
The guideways are generally made of steel or reinforced concrete to provide stability, strength and longevity.

Attraction and repulsion
The train's magnets are pulled toward a coil when its pole is opposite to it and pushed away when the poles are the same.

Electric supply
An electric charge runs through coils embedded in the track, magnetising them.

Magnetic coils
As the electricity passes through each coil, the polarity changes.

Propulsion
The pull comes from in front of the train and push once it has passed. This propels the train forward.

"In 1966, rockets were all the rage, so naturally someone decided to pop a couple onto a train"

The secret behind reaching these incredible speeds is electromagnets. The maximum speed of conventional trains is limited by how powerful the engine is and how fast the wheels turn, but magnetic levitation (maglev) trains have neither of those drawbacks. This is mainly because they don't have engines or wheels! They hover between one and 10 centimetres (0.4 and four inches), suspended by magnets – both on the track and under the train – which repel each other. Magnetic coils ahead of the train are turned on, pulling the train forward with magnetic attraction. As the train reaches the coil, the magnet is turned off and the next one is turned on. The aerodynamic design of the train, together with the absence of friction from wheels and the strong electromagnetic forces, contribute to incredible speeds of up to 430 kilometres (267 miles) per hour.

High-speed trains are constantly being developed and improved. In Germany, engineers have developed an electromagnetic suspension (EMS) system, called Transrapid. This utilises regular electromagnets and an additional set of magnets to guide the train. This prevents the carriages from rocking during turns by wrapping the Transrapid around the guideway, while the maglev sits on a cushion of air. It's reported that these EMS system trains are able to reach blistering speeds of 482 kilometres (300 miles) per hour.

In Japan, a new system currently being developed is called electrodynamic suspension. This involves the electromagnets being super-cooled and conserving energy, making the system much more efficient in terms of energy use, but is very expensive. Another downside to this system is that it needs to run on rubber tyres until it reaches a speed of 100 kilometres (62 miles) per hour, which causes unwanted friction.

The latest development to come out of the world of high-speed train travel is the Inductrack. This uses normal magnets that don't have to be super-cooled or electrically powered, but do involve the train using its own energy source to get up to speed and levitate before the magnets are able to pull it along. These magnets are made from a revolutionary neodymium-iron-boron alloy that dramatically increases the power of the magnetic field.

Who dreamt up magnetic trains?

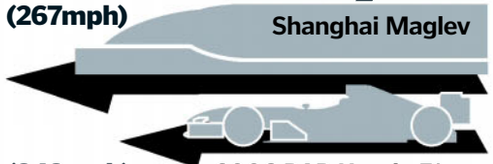
The idea for magnetic levitation was first proposed in 1914 by Frenchman Emile Bachelet, who developed the rather brilliant idea of a series of magnets being turned on and off along a track to pull a train along. It didn't catch on back then, however, due to the spotty reliability of the electricity supply, but paved the way for the incredible, superfast technology we see today. The improvement in electric technology and the streamlined shapes of trains have allowed them to go faster and faster until they have reached the amazing speeds we see today in the Shanghai Maglev and Japanese Shinkansen.

Shanghai Maglev

The Shanghai Maglev is currently the world's fastest commuter train, reaching a top speed of an eye-watering 430 kilometres (267 miles) per hour, and that's just its operating speed. In testing it hit 500 kilometres (311 miles) per hour. It transports passengers along the Shanghai Maglev Line from Shanghai's Pudong Airport to the Longyang Road train station. The track is 30.5 kilometres (19 miles) long, with a journey time of just seven minutes and 20 seconds, as it travels at an average speed of 251 kilometres (156 miles) per hour. It has been running since 31 December 2002 and available to the public since 2004, so has held the record for the fastest commuter train in the world for an astonishing ten years, a monumental achievement in an industry where innovation and improvement seems to happen with incredible regularity.

Train stat-ion

430km/h (267mph) Shanghai Maglev



(249mph) 400km/h 2006 BAR Honda F1 car

111 HOURS
It would take the AGV Italo 111 hours to circle the equator

7 BILLION
Shinkansen trains have carried over seven billion passengers since 1964, that's the population of the entire planet. To date, there has not been a single accident

KEY DATES
HIGH-SPEED TRAIN HISTORY

1914
Emile Bachelet first proposes using magnets to raise a train in the air, reducing friction.

1964
Japan builds its first maglev railway, just in time for the Tokyo Olympics. It can reach 210km/h (130mph).

2004
The Shanghai Maglev train takes passengers for the first time, making it the fastest commercial train in the world.

2013
USA announces plans to join the high-speed revolution with a 322km/h (200mph) train between San Francisco and Los Angeles.

2014
China announces plans for a super-maglev that will reach 2,900km/h (1,800mph) by building a vacuum tunnel.

DID YOU KNOW? *Friction through driving and braking loses a single InterCity train wheel 68kg (150lb) of steel in its lifetime*

Battery

The key to making the most out of the phenomenal amount of energy potential in regenerative braking systems is how to store it. That's why places like Philadelphia's Southeastern Pennsylvania Transportation Authority have installed a huge battery that can hold a megawatt of electricity. That is enough to boil 7,500 litres (1,981 gallons) of water. Power produced from regenerative braking or any of the other energy-gathering technologies is delivered here. They can then use this power to run trains or, if there is more than they need, they can sell it, so not only are they saving the environment but making money too!

Regenerative brakes

Traditional brakes work by clamping onto the wheels of the vehicle and slowing it down through friction. However, this wastes energy by turning it into heat. Regenerative brakes reverse the electric motor so it stops producing electrical energy for forward motion and instead converts the vehicle's momentum into stored energy that it can use to set off again. Alternatively, it can send that power down the track for other trains to use. This fantastic innovation not only helps to stop trains but now creates power when before it was lost, making the whole process much more efficient.

Sensors

An incredible amount of weight and pressure is placed on train tracks and, although it doesn't waste energy, there is still a lot that can be harvested from it. To gain energy from the weight of the train, piezoelectric crystals are placed under the tracks. They have an amazing property that makes them release an electric charge when pressure is put on them. As the train thunders over these crystals, they are squashed, release a charge and turn that into electrical energy that can be used in a variety of areas. Each one can be used time and time again, providing free, renewable energy.

Energy-saving technology

One of the main frustrations in train travel is the energy lost in braking as a train pulls into a station. However, developments in braking technology has found a way to not only reduce the energy lost in braking but turn it back into electrical energy to use when starting up again. This could revolutionise train manufacturing, as trains will need much less powerful engines to haul themselves from a standing start. In fact, regenerative brakes are just one of a long line of ways energy can be saved and created.

Turbines

Designers in Italy, Korea and China have plans to start putting wind turbines in train tunnels and on tracks underneath the trains to harvest energy. As the train whooshes past, the wind flies into the turbines, which generates electricity using wind power. Again, this is successfully harnessing power created by the train to create energy for use on the track or in the community.

"A train arrives at one of Shinjuku Station's platforms every three seconds on average"

Eight incredible railways and trains

Ever since the first working railway was created in England over 400 years ago, in 1603, engines have evolved from primitive coal-powered mechanisms to super-efficient electric motors, meaning that they are able to travel much longer distances, both faster and with less resources for each unit of power. However, this has also meant that humans have had to get constantly more creative with the ways they overcome the challenges of travelling over and under – and sometimes straight through – tricky terrain. Through incredible and imaginative engineering, trains are now able to go over mountains, through hills and even under the sea. There are some lines that represent the dream of a life of luxury, while others are a daunting experience you probably wouldn't want to repeat in a hurry! But which are the most extreme of all?

The world's most dangerous railway

One of the most dangerous railways in history is the Chennai-Rameswaram railway line, which links mainland India with the island of Rameswaram. In 1964 the train, which still has to battle furious crosswinds, was hit by a huge tidal wave, knocking it off the tracks, killing all 115 people on board and demolishing part of the track. Although it has been rebuilt to be safer, it still crawls along the bridge at just over eight kilometres (five miles) per hour.

STAT

The Chennai-Rameswaram train travels at around the same speed as a swimming penguin

The world's longest

If you want to get across the world's largest country, you'll need the world's largest railway. Back in 1891, the Russians built the Trans-Siberian Railway. It spans over 9,200 kilometres (5,700 miles) and transports vital goods like oil, coal and grain. It was finished in 1916 and linked the inhospitable Siberia with the rest of Europe and Asia. Four kilometres (2.5 miles) of track were laid every day using stone to provide a stable surface in the swampy stretches and light metal and wood for the tracks themselves.

STAT

The Trans-Siberian Railway cost around seven times as much as the Golden Gate Bridge.

The world's highest

If you've got a head for heights, it could well be worth taking a trip on the world's highest railway, taking you from China to Tibet. It's called the Qinghai-Tibet railway and treats passengers to incredible views across the Qinghai-Tibetan Plateau. The Lhasa Express reaches a dizzying 5,072 metres (16,640 feet) high with an average elevation of over 4,000 metres (13,123 feet) above sea level. It also houses the world's highest railway station, the Tanggula, which sits at 5,068 metres (16,627 feet) above sea level.

STAT

The highest point of the Qinghai-Tibet railway is 262m (860ft) higher than Mont Blanc

The world's lowest

The Seikan railway tunnel connects Japan's Honshu and Hokkaido islands and sits 140 metres (460 feet) underneath the seabed, making it lower than any other railway. It was built between 1971 and 1988 and will be able to accommodate the superfast Shinkansen from 2016. The tunnel itself is nearly 54 kilometres (33.6 miles) long, with just under half of it below the seabed. 50 train journeys go through it every day, transporting people and freight between the two islands.

STAT

The tunnel used 85,000 tons of cement, enough to build a 10m (33ft)-wide wall higher than Burj Khalifa

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch this cool video of the Shanghai Maglev

www.howitworksdaily.com

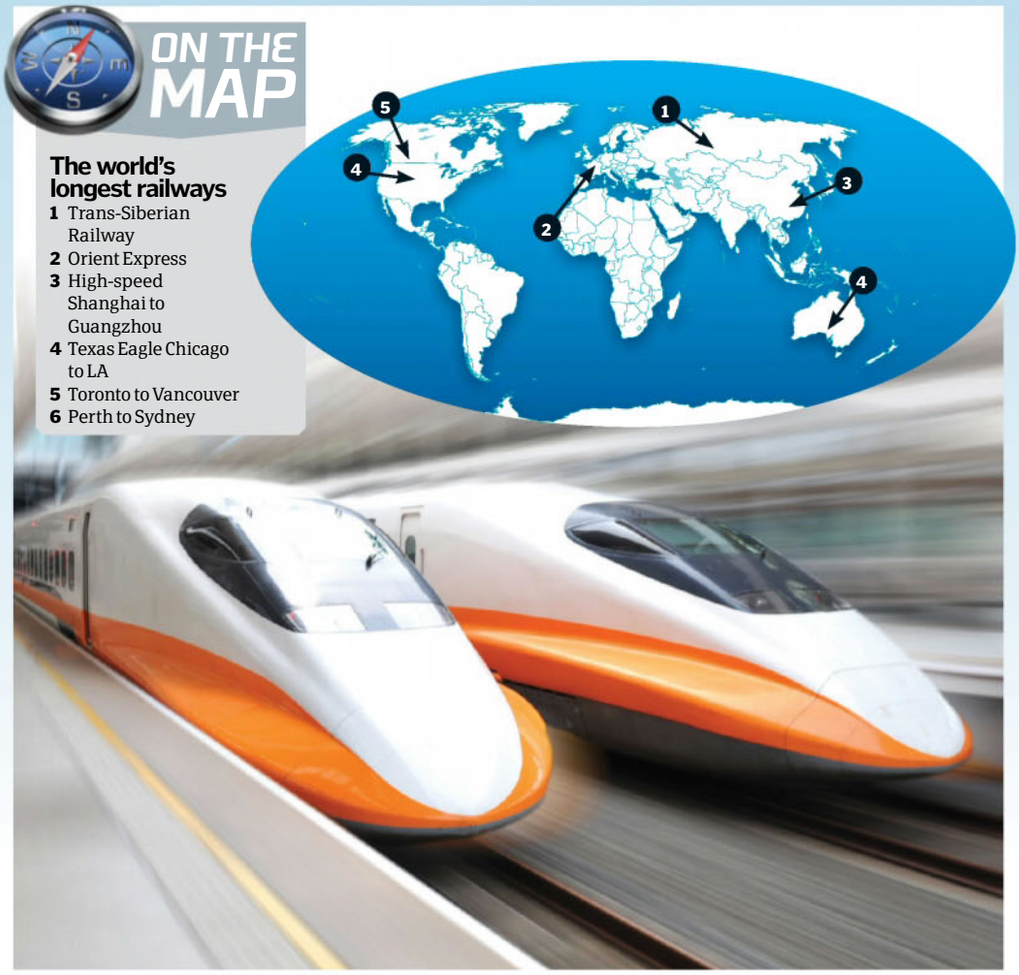
DID YOU KNOW? *The USA has the longest rail network in the world, but no trains that qualify as high-speed ones*

The world's busiest train station

The Shinjuku Station in Tokyo is the world's busiest station, seeing an astonishing 3.64 million passengers board trains every day. There are 200 exits at the station in order to serve the huge numbers of people that come through its doors daily. A train arrives at one of its platforms every three seconds on average. The most popular line by far is the JR line, which takes nearly half the passengers who use the station.

STAT

More people use the Shinjuku Station every day than live in the country of Latvia

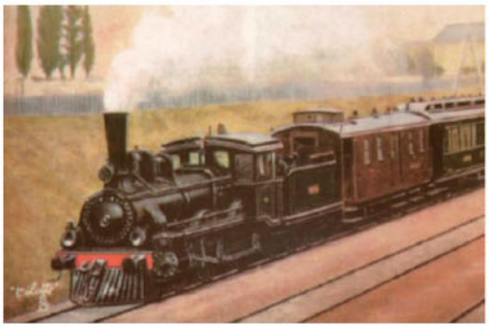


The world's longest station platform

In October 2013, work was completed on the longest train platform in the world. It measures a vast 1,366 metres (4,482 feet) and spans the length of the Gorakhpur railway station in India. When they built the station, they made sure they had the world's longest platform, eclipsing the previous record, which also happened to belong to a train station in India, by 294 metres (965 feet).

STAT

It would take Usain Bolt at least two minutes and 11 seconds to run the length of the Gorakhpur platform



The world's most famous train

If you're asked to name a train, you'll probably either say Thomas the Tank Engine or the Orient Express. As one is fictional, we'll focus on the one that travelled between Paris and Istanbul for 94 years, before being discontinued in 1977. It had four sleeping cars, each of which held ten compartments for snoozing in. It wasn't a technological marvel, but its romantic mystique kept it chugging away for the best part of a century.

STAT

The Orient Express took 60 hours to travel the 3,000km (1,864mi) between Paris and Istanbul

The world's oldest working train

Built by the UK-based Kitson, Thompson & Hewitson in 1855, the EIR-21 and EIR-22 steam locomotives are still running, transporting passengers between the cities of Alwar and New Delhi in India. Weighing in at a hefty 26 tons, each train can deliver 97 kilowatts (130 horsepower) and can reach 40 kilometres (25 miles) per hour. That's not bad for an almost 160-year duo of steam locomotives...

STAT

In the 159 years since EIR-21 and EIR-22 were built, Britain has had six different monarchs

"Mirrors create blind spots, which can lead to danger as a driver cannot see certain points around a vehicle"

The Smart Rearview Mirror

Nissan's innovative technology leads the way when it comes to looking backward

One of the most important safety aspects to a vehicle is the ability to provide good all-around vision to its driver. A huge glass windscreen means looking forward isn't an issue, but being able to see down the side and out the back of a vehicle is slightly trickier. For decades, vehicles have employed a variety of mirrors to combat this, with external wing mirrors and an interior rear-view mirror not just commonplace but also required by law in most countries. However, mirrors create blind spots, which can lead to danger as a driver cannot see certain points around a vehicle. Using live camera feeds and screens instead of mirrors is now becoming a viable solution to this age-old problem.

Earlier in 2014, Japanese automotive manufacturer Nissan debuted its variation of this technology, named Smart Rearview Mirror, at the New York Motor show on its US-only Rogue model.

The Smart Rearview Mirror works by a small camera, mounted in the rear window of a vehicle, projecting live to the driver via an LCD monitor mounted within the frame of a traditional rear-view mirror. The driver is afforded a better view of the environment behind the vehicle, minimising blind spots – and as the camera is mounted at the rear of the car, the driver doesn't have to look past the interior and C pillars of their own vehicle to the world outside.

What's more, the technology is switchable, so drivers can choose whether they'd like to use the camera and LCD monitor or the traditional mirror method when viewing the environment at the rear of a vehicle, with the simple press of a button.

The Smart Rearview Mirror in action

Here's how Nissan's innovative tech will help inform the driver of what's happening behind the vehicle

The safety revolution will be televised

The Smart Rearview Mirror is the latest innovation in a long line of technologies instilled in an automobile to improve its overall safety – with many features designed to work effectively in tandem with others.

With Nissan, the Rogue has many such features, including Around View Monitor, which stitches together images from four different cameras to produce an all-encompassing, top-down view from the rear of the car, which is invaluable when spotting smaller hazards such as bollards or running children when reverse parking in town.

Another great Nissan feature is Moving Object Detection, which provides an audible warning when another object moves while the car is reversing, helping to avoid a rear-end smash.

All of these safety features work in tandem to reduce the risk of driver error behind the wheel, in this case by providing greater vision at the rear of the vehicle.

THE STATS
MS TURANOR PLANETSOLAR

90 tons WEIGHT | 35 metres LENGTH | TOP SPEED 26km/h | 120kW POWER | 809 SOLAR PANELS | 0 CARBON EMISSIONS

DID YOU KNOW? *'Turanor' means 'power of the Sun' in Sindarin elvish, a language invented by JRR Tolkien*

Solar-powered boats

Utilising the Sun's energy for nautical journeys

Shipping accounts for 2.7 per cent of all global carbon dioxide emissions (aviation in comparison is less than two per cent). If the amount of carbon in the atmosphere is going to be reduced, maritime travel is one of the key sections to address. Sailing is a tried and tested format, but what about solar power?

A strong candidate for the solar-powered boat crown is the MS Turanor PlanetSolar from the project of the same name. The largest solar-powered boat on Earth, it contains over 500 square metres (5,382 square feet) of solar panels that drive the vessel's two electric motors. The catamaran doesn't generate any carbon emissions and for travel at night or prolonged heavy cloud cover, lithium-ion batteries are used. The boat crossed the Atlantic in 22 days (a record for a solar-powered vessel) and can navigate for up to 72 hours in the dark on battery power. The Turanor is also completely silent so noise pollution is another eliminated problem.

Solar energy has also been proven to work on smaller, less expensive craft. Recently, Englishman Simon Milward created his own small vessel, which successfully crossed the Channel. It's still early days but if the use of solar power can catch on in the maritime world, traversing the seven seas in an environment-friendly way could be a massive step in reducing the human carbon footprint.

With 809 panels, the MS Turanor could easily be known as 'solar panels with a ship attached'

An unusual voyage

We speak to Simon Milward, the first person to cross the Channel using solar power

How did you construct this solar-powered boat?

The boat (called AKT Solar) is made from the base of a Dart 15 racing catamaran. It has a wooden frame fitted on top. Six AKT solar panels are then mounted on top and two electric motors are mounted to the transom of the frame. The panels are wired directly into the electric motors.

Did you run into any problems?

About three quarters of the way through, in the second shipping lane, the wind and waves picked up. I was worried that the waves might swamp the motors meaning I wouldn't be able to navigate a path between the ships. But fortunately the boat rode over the waves well and the motors kept relatively dry and were not damaged.

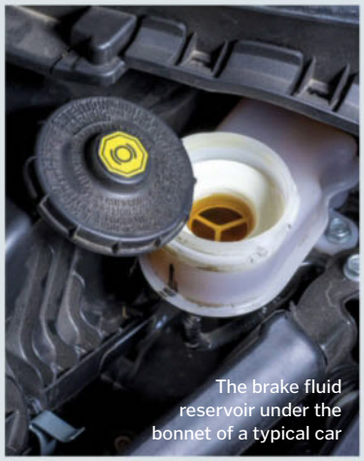
Was the technology used in the boat a total success?

Yes, completely. No problems, even with the salt water, as the AKT solar panels are waterproof and the motors adequately protected. From the point of view of speed, the technology was also successful. Guinness World Records said we needed to cross the Channel in under 12 hours for them to recognise the record and we made it across in six hours and 59 minutes.

Brake fluid

The science behind the essential liquid under the bonnet

As cars get ever faster – the Hennessey Venom GT can reach an eye-melting 300 kilometres (186 miles) per hour in 13.63 seconds – the brakes used to stop them must stay up to speed. Braking in cars would not work without the fluid. Brake fluid works because it does not significantly compress. As you press the brake pedal, the force is transferred to pressure in the fluid. This pressure causes the brake pads to squeeze the wheels, converting the kinetic energy to heat via friction and slowing the car down. As a result, it is essential that the fluid has a high boiling point so it doesn't evaporate after prolonged use. If it does begin to evaporate, the effectiveness is seriously compromised because gas can be compressed much easier than a liquid. The boiling point of the fluid is measured in DOT numbers, which stands for the US Department of Transportation. DOT 3, 4, and 5.1 are made of glycol and DOT 5 is silicone based. It is recommended your brake fluid is changed every two years.



The brake fluid reservoir under the bonnet of a typical car

"It means surveillance aircraft are able to remain in the air for much longer periods of time"

Refuelling in mid-air

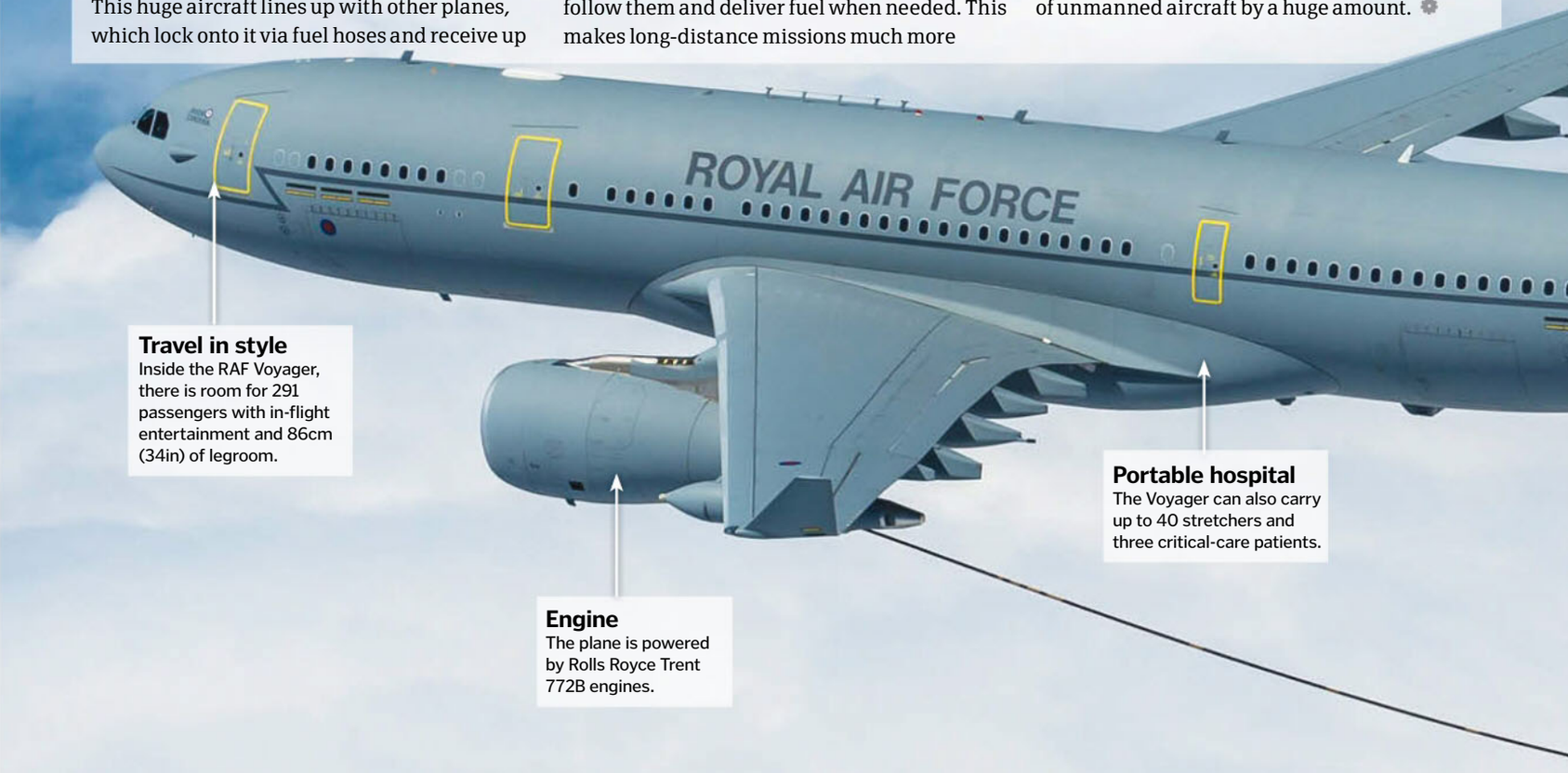
How planes are able to keep flying for days thanks to airborne petrol pumps

You might think that filling your car up at the petrol station is a bit of a tiresome task, fiddling around with the fuel cap and trying to squeeze the pump so you reach a nice round number. Imagine doing that thousands of metres in the air, travelling at hundreds of kilometres an hour.

This is the task that faces every pilot that flies a plane like the RAF Voyager, an aircraft designed to refuel planes while still in the air. This huge aircraft lines up with other planes, which lock onto it via fuel hoses and receive up to 1,200 kilograms (2,646 pounds) per minute of fuel from the pods underneath each wing. This is really useful as it means surveillance aircraft are able to remain in the air for much longer periods of time, so they don't lose targets or give away crucial secrets – like where their base is – by repeatedly returning there to refuel.

Another benefit is that fighter planes can lift off with less fuel than usual and more weaponry, because the refuelling plane can follow them and deliver fuel when needed. This makes long-distance missions much more practical and worthwhile. Each aerial refuelling has to be executed with pinpoint precision, with highly skilled pilots manoeuvring themselves into position while still going at huge speeds.

Autonomous aerial refuelling is also in development, using planes to latch onto drones and fill them with fuel for their flight. This will also need incredible accuracy but will be massively useful as it could extend the airtime of unmanned aircraft by a huge amount.



Travel in style
Inside the RAF Voyager, there is room for 291 passengers with in-flight entertainment and 86cm (34in) of legroom.

Engine
The plane is powered by Rolls Royce Trent 772B engines.

Portable hospital
The Voyager can also carry up to 40 stretchers and three critical-care patients.

How to refuel a plane

A step-by-step process of keeping a fighter jet topped up with fuel

Lower the hoses
A 27.4m (90ft) hose is stored in each wing. At the command from the mission system operator (MSO), they are released and unwind through an opening in the wing. Each hose has a basket on the end that will be caught by the following plane.

Locking on
The aircraft to be refuelled extends a probe and flies toward the hose so the probe enters the basket. Once this connection has been made, the MSO is able to give the order for the refuelling to begin. Once finished, it slows down and the hose disconnects.

THE STATS
RAF VOYAGER

UP TO 1,200 kg/min POD FUEL TRANSFER

MAX WEIGHT 233 tons

FUEL CAPACITY 111 tons

43 tons PAYLOAD

15,000km RANGE

60.3 metres WINGSPAN

DID YOU KNOW? *The first aerial refuelling took place in 1921 when Wesley May wing-walked between biplanes carrying a gas canister*

Riding with the RAF Voyager

How this epic feat of engineering is able to fuel up planes on the move

There are currently nine of these amazing aeroplanes providing vital fuel for RAF aircraft with five more on the way in the next few years. Each Voyager is capable of carrying an incredible 111 tonnes of fuel and 43 tonnes of freight in its cargo hold. This means it can respond to most calls from a great distance away as it has both the fuel range and ability to hold supplies for long journeys.

Previous life
Each of the 14 Voyager aircraft started life as an Airbus A330-200.

Doubling up
Two planes can be refuelled at the same time, as hoses drop from each wing.

For thirstier planes
Larger planes can lock onto the tail of the plane and receive an incredible 1,800kg/min (3,968lb/min).

Gas guzzlers
The Voyager is able to refuel RAF Tornado, Typhoon and C-130 Hercules planes.

Fuel transfer
Up to 1,200kg/min (2,646lb/min) of fuel is transferred from the Voyager to each plane.

Magnificent robots in their flying machines

NASA is also active in the field of aerial refuelling, leading the research into autonomous refuelling, which is where unmanned aircraft can receive fuel from another unmanned tanker.

The aircraft they are using for these experiments are Global Hawks, one of which has been specially prepared to receive fuel and the other to provide it. They line up with one another, before the lead aircraft drops the hose down to the following aircraft, which detects the hose's position and locks onto the drogue, which is a funnel on the end of the hose.

HOMES OF THE FUTURE

Now that smartphones are everywhere, get ready for the smart home!

We've all been there. Halfway to the airport and suddenly gripped by the unshakable fear that we've forgotten to switch off the oven or lock the windows. With a smart home, you can put your mind at rest and fix any little oversights, all from your phone as you speed toward your flight.

In a smart home, all the electronic devices are connected to one another in one controllable network, allowing inhabitants to interact with their homes like never before and offering greater comfort, convenience, personalization, energy savings and opportunities for fun!

Want your coffee maker to crank up downstairs as soon as you throw back your sheets? A smart home will let you arrange that. Want to start the bread maker churning and the pool heating as you leave the office? You can do that too. Want your home to learn your habits and help cut your energy consumption, or to notify you if it senses anything untoward like an intruder? No problem at all.

The basis for all these technological advances is the 'Internet of Things' – the exponentially expanding web of devices that are connected to the internet, allowing them to talk to each other and to you, transforming the way we live. ▶

Smoke detector
Alerts you by text if there's a problem at home or its batteries are running low.

Smart bulbs
Create atmosphere without leaving your seat, by fine-tuning intensity and hue from your tablet.

Movie night
Selecting 'movie' setting dims the lights, activates surround sound, fires up the popcorn maker and lowers the shades.

Digital discipline
Shut off the computer, TV or lights remotely from the sofa when it's past children's bedtime.

5 TOP FACTS
SMART HOME STARTER KITS

1 Smart socket
For just £40 ($67), the Belkin WeMo switch transforms ordinary electronic devices into smart gadgets you can control and schedule from your phone.

2 Leading light
A LIFX LED smart bulb might set you back £80 ($135), but will reward your investment with 27 years of kaleidoscopic colour and smart functionality.

3 Thoughtful thermostat
By learning and adapting to your schedule, the Nest Learning Thermostat should pay for its £180 ($300) price tag within a couple of years in most UK households.

4 Smoke signal
Smoke and CO detector Nest Protect will talk to you before howling, so you can deactivate it, discard your burnt toast and save face. Not bad for £90 ($150).

5 Security surveillance
The Canary home security system, available soon for about £120 ($200), is a pint-sized surveillance unit that alerts your phone if it detects unusual activity while you're out.

DID YOU KNOW? *The USA's smartest home is owned by SmartThings CEO Alex Hawkinson and includes over 150 connected devices*

Surveillance unit
Live video sent to your phone puts your mind at rest while at work or on holiday.

Smarter slumber
Bed tracks your sleep cycles and sleep quality, activating the coffee maker at the first signs of waking.

Sun shades
Open and close automatically according to the amount of direct sunlight.

Smart thermostat
Saves you money on energy bills by learning your habits and cranking down automatically while you're gone.

Washing machine
Can delay start until energy prices are cheapest, and will text you when laundry cycle is complete.

Intelligent fridge
Enters sleep mode while you're out of town, suggests recipes based on contents and alerts you of low inventory or expiring items.

Talking to your tech
Tracking the growth of the Internet of Things

20% NUMBER OF USA ADULT INTERNET USERS WHO ALREADY OWN A DEVICE THAT CONNECTS THE PHYSICAL ENVIRONMENT TO THE INTERNET [FORRESTER]. THIS WILL RISE TO 50% BY 2020 [PARK ASSOCIATES]

1.5 million NUMBER OF FULL HOME AUTOMATION SYSTEMS INSTALLED IN THE USA IN 2012 [ABI RESEARCH]

224 million NUMBER OF HOMES WORLDWIDE (1 IN EVERY 8.5 HOMES) THAT WILL HAVE SOME SORT OF SMART HOME TECHNOLOGY INSTALLED BY 2019 [STRATEGY ANALYTICS]

10% NUMBER OF US HOMEOWNERS AGED 25-34 WHO OWN AT LEAST ONE SMART ENERGY DEVICE [PARK ASSOCIATES]

1 in 9 (11%) NUMBER OF UK HOUSEHOLDS THAT WILL BE USING AT LEAST ONE SMART DEVICE BY THE END OF 2014. THIS NUMBER WILL JUMP TO OVER 1 IN 4 (27%) JUST FIVE YEARS FROM NOW [STRATEGY ANALYTICS]

$7.8 billion (£4.6 BILLION) PREDICTED SIZE OF THE DIY SMART HOME MARKET BY 2019, UP FROM $1.3 BILLION (£770,000) TODAY [NEXTMARKET INSIGHTS]

150 NUMBER OF INTERCONNECTED DEVICES IN USA'S 'SMARTEST' HOME [HUFFPO VIDEO INTERVIEW WITH OWNER]

20% AMOUNT AN AVERAGE USER COULD SAVE ON THEIR ENERGY BILL BY INSTALLING A NEST LEARNING THERMOSTAT [NEST]

7% THE NUMBER OF US HOMES WITH PROGRAMMABLE THERMOSTATS JUMPED BY THIS MUCH BETWEEN 2012 AND 2013 [CONSUMER ELECTRONICS ASSOCIATION]

£234 OR $393, AVERAGE TECHNOLOGY SPEND OF UK SMART-HOME OWNERS, LESS THAN HALF THAT OF THEIR US EQUIVALENTS (£517 / $868) [STRATEGY ANALYTICS]

"'It's movie time' might lower the shades, dim the lights, activate your sound system and fire up the popcorn maker"

Automated home electronics have been on the scene for decades, but only recently have they been able to begin talking to one another and functioning in concert. That's largely thanks to the advent of efficient low-cost wireless protocols – think Wi-Fi, Bluetooth, mobile phone networks – in the early-2000s, which use radio waves to transmit messages wirelessly.

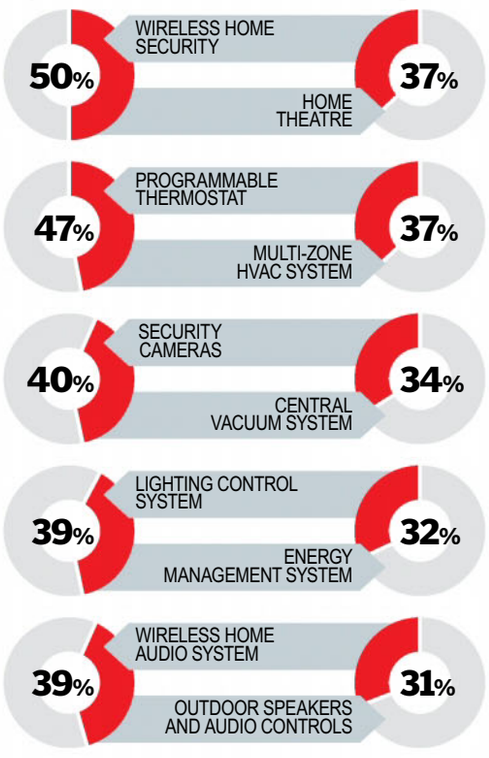
ZigBee and Z-Wave are similar protocols that can be thought of as low-power, short-range versions of Wi-Fi. They are ideal for use inside the smart home because they're optimised for transmitting small amounts of data – like messages to and from smart devices – through walls and furniture, over the range needed for a typical household.

Smart devices are connected via these wireless networks to a central hub where they can be controlled with a tablet or smartphone. They can also be programmed to carry out any action based on the logic command 'If This Then That', or IFTTT (rhymes with lift). IFTTT lets you dictate what action a device should take for a given stimulus.

For example, announcing to your TV, "It's movie time", might lower the shades, dim the lights, activate your surround sound system and fire up the popcorn maker. Now that's smart.

Homeowner wish list

Top ten most coveted smart technologies*



*data from National Association of Home Builders

Smart locks
Grants keyless entry to family members and guests with time-restricted access codes – handy when struggling with groceries!

Garage door
Opens as your car approaches the property and can be locked and unlocked remotely.

Motion sensors
You'll receive a text when doors or windows open, alerting you to potential intruders and helping to keep tabs on pets and kids.

Heated driveway
Embedded radiant heat system kicks in to melt snow and ice when temperatures plummet.

Welcome home!
Outdoor lighting and illuminated walkways brighten as you approach the property.

RECORD BREAKERS
SMART MANSION

$120 MILLION

MOST VALUABLE SMART HOME

Bill and Melinda Gates's Pacific lodge-style smart mansion in Medina, USA, is nicknamed Xanadu 2.0 after the title character's estate in *Citizen Kane*.

DID YOU KNOW? *X10, a wired connection system made in 1975, was one of the earliest smart-home systems and is still in use today*

THE SMART OUTSIDE

Sprinklers
Override their program to turn off when it rains and on if the soil becomes too dry.

Pool party
Water temperature can be set on your drive home, ready for your evening dip.

Attentive awnings
They adjust themselves automatically as the Sun moves overhead.

Surveillance system
Keeps an eye on the kids in the pool, and knows the difference between pets and an intruder.

Occupied home simulator
Activates lights and shades to give an impression of habitation while you're away on holiday.

"The barriers in terms of cost and heaviness of the install [has] start[ed] to go down"

Until recently, smart homes have mostly been viewed as quirky playgrounds reserved for the super-rich and diehard *Jetsons* fanatics. In the US today, less than one per cent of homes have a full automation system installed, but the picture is changing rapidly. Why?

"What's happening is there's a shift from that past market – which required a professional installer, and more recently a service-provider subscription – to what we're starting to see now: the roll-out of what we call DIY smart homes", explains chief analyst and smart-home expert Michael Wolf of NextMarket Insights in Seattle.

The majority of new smart objects are designed to plug-and-go. New smart-home residents can shop around for devices that best meet their needs, download the apps that make them run, stitch them all together through their humble smartphone, and save themselves a fortune in the process. "That's where we see the potential for much greater adoption, because the barriers in terms of cost and heaviness of the install start to go down", says Wolf.

In 2014, tech giants have rushed to make their first forays into the smart-home market, steering it firmly toward the mainstream. In January 2014, Google acquired Nest Labs – founded by iPod designer Tony Fadell – for £1.9 billion ($3.2 billion). Nest's most popular product, the Learning Thermostat, responds to your routines and preferences, turns itself down when it notices you're away, helping you save energy.

Elsewhere, Microsoft formed a partnership with smart hub and device company Insteon in May, and in June Apple announced that its own Siri-integrated smart-home platform HomeKit would debut as part of the upcoming iOS 8 release this autumn.

So if smart homes offer improved comfort, convenience, security and environmental credentials, for an affordable price, what's the catch? For one thing, the explosion of new products, all running on different protocols, can be hard to integrate; less tech-savvy consumers might want to hold off a year or so while the industry reaches a better consensus.

More troubling is that smart homes, like any internet-connected device, are potentially hackable. What if a burglar finds a way to open your smart lock and disable your intelligent security systems? Others worry that products like Nest give Google even deeper reach into our personal data.

One thing is for certain: whether you're set to be an early adopter or you're still on the fence, this is only the beginning for smart homes.

Next big things

Welcome home! Check out some of the features of your oh-so-smart future abode...

Witt induction hobs

www.witt-ltd.com

Induction multizones sunk into the work surface automatically detect where a pan is placed; shut off when a pan is removed, overflows, or boils dry; and offer a pause function if you need to walk away suddenly.

Feed & Go Online Automatic pet feeder

www.feedandgo.com

All the scheduling and dispensing features of a traditional automatic feeder, plus a camera so you can share every gory detail of your pet gobbling up its dinner, and a voice recorder so you can leave it a secret mealtime message.

Lifx LED Bulb

lifx.co

Lets you set endless moods, selecting from over 16 million possible hues in a colour wheel on your smartphone. Can be programmed to brighten and dim slowly at opposite ends of the day, easing you out of and into sleep; to flash when you receive a text or email; and to come on automatically as soon as it detects your smartphone approaching your property. Highly energy efficient, it lasts 27 years.

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Watch a glimpse of your future home!

www.howitworksdaily.com

DID YOU KNOW? *A planned miniature smart home for dogs, T-Pai is shaped like a double-decker bus and includes video-call facilities*

Nest Protect

nest.com

Combined smoke/carbon monoxide detector gives you a heads up before sounding the full alarm, texts you when its batteries are low, alerts you of hazards detected while you're out and will shut down your Nest Thermostat if it sniffs something untoward.

Belkin WeMo Switch

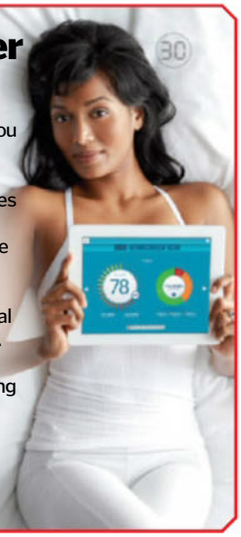
www.belkin.com

Lets you control any electric appliance remotely from your smartphone. Options to monitor how much energy your devices are consuming, or pair with a motion sensor so that, for example, walking through the front door turns on an appliance in another room.

Sleep Number Sleep IQ

www.sleepnumber.com

Sleep IQ monitors you as you sleep, tracking your heart rate, breathing rate, movements and sleep cycles to calculate the quality of your sleep and help you fine tune details like your bed time, mattress texture and daily habits to attain optimal sleep each and every night. Especially useful if your bedfellow is prone to snoring – Sleep IQ responds to the voice command "Stop snoring!" by gently raising your partner's head while they continue to slumber.



HomeChat by LG

lgusblog.com

With HomeChat you can converse naturally with your appliances to find out what they're up to and make requests. Your fridge might text you to remind you you're running low on milk; you can ask the washing machine, "where are you up to and when will you be done?" You can also set the robot vacuum to work an hour before you return home. They probably won't have any useful relationship advice for you, though.

PointGrab's PointSwitch

www.pointgrab.com

This nifty gadget allows you to control multiple appliances – lights, entertainment systems, air-con and more – from across the room simply by pointing and gesturing, so you won't even need to pick up your smartphone. PointSwitch uses motion-detection algorithms with a standard two-dimensional infrared camera to accurately identify your gesture and its direction. Just remember to turn it off before you start dancing on your own in the lounge...

Elertus Smart Sensor

www.elertus.com

Originally designed to monitor the temperature and humidity of cellars housing prize wines, the Elertus has ballooned into an all-encompassing watchdog that keeps tabs on anything precious to you. As well as clocking temperature and humidity, it will alert you if it detects movement, water, changes in light levels or doors opening and closing.

LED light transmissive carpet

www.philips.com

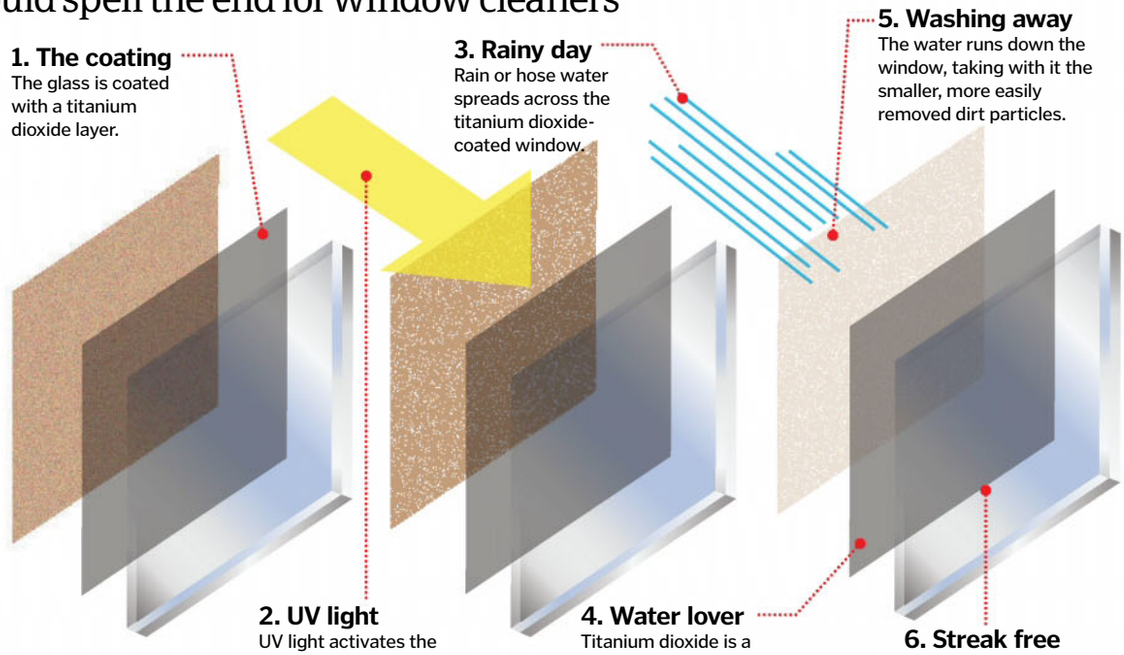
Carpet transmits light from programmable LED arrays laid underneath it. Use it to highlight the route to the bathroom in the night; guide inhabitants to safety during a fire; deliver instructions, directions or greetings to house guests; or – best of all – recreate the music video for *Billie Jean* right there in your living room. Maybe. No, definitely.

"These bubbles rupture under pressure, creating tiny vacuums that act like suction cups"

Self-cleaning glass explained

The technology that could spell the end for window cleaners

Cleaning windows can be an absolute chore, especially if they are high up. Luckily, a new invention on the market could mean the days of chamois leather, a bucket and a ladder are reduced to a distant memory. Glass is coated with a chemical compound of titanium dioxide that is activated by UV light. This compound reacts with dirt, breaking it down into tiny particles. This makes it much easier for the dirt to be washed off with just a quick blast of a hose. Even ordinary rain is enough to work away the smaller, looser dirt particles. This is because of the compound being hydrophilic, making water spread all over the surface, rather than streak down in droplets.



1. The coating
The glass is coated with a titanium dioxide layer.

2. UV light
UV light activates the layer which reacts with dirt, breaking it up into much smaller pieces.

3. Rainy day
Rain or hose water spreads across the titanium dioxide-coated window.

4. Water lover
Titanium dioxide is a hydrophilic substance, which means water wants to cover as much of it as possible.

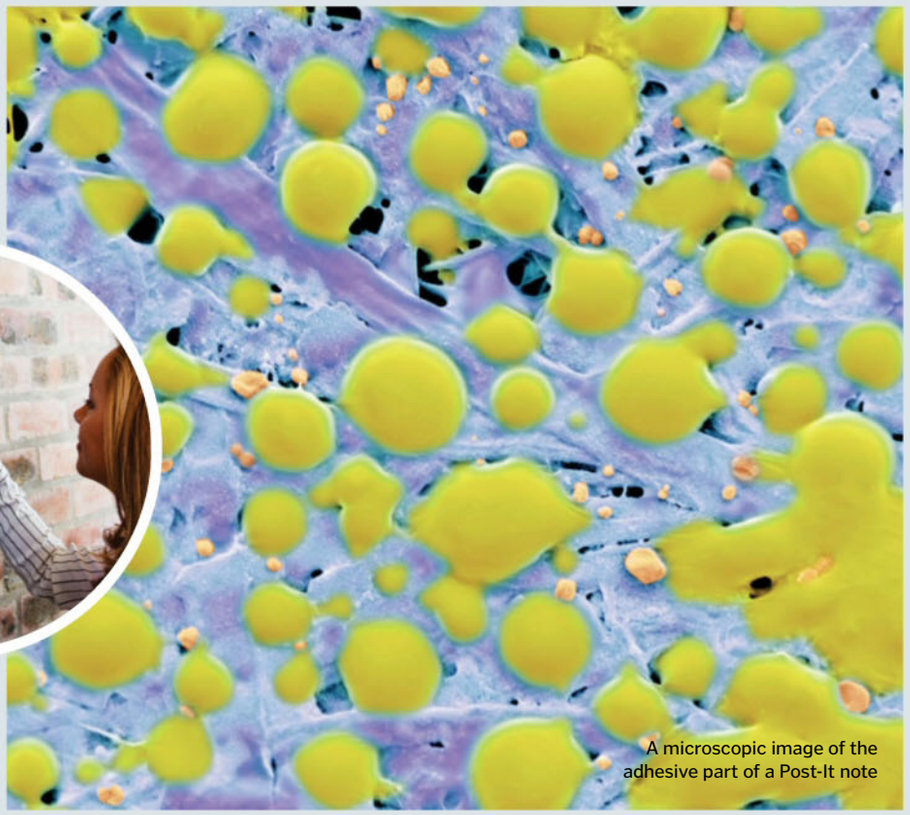
5. Washing away
The water runs down the window, taking with it the smaller, more easily removed dirt particles.

6. Streak free
As the water has spread into a sheet rather than droplets, it leaves clean, streak-free windows.

What's in a Post-It note?

The incredible science behind sticky paper memos

Each Post-It note has a strip of pressure-sensitive adhesive on the back. The adhesive enables notes to stick to a surface, but it does not bond too tightly so notes can be easily removed. The exact composition of Post-It adhesive is a closely guarded secret, but chemists who have studied it believe the glue contains microscopic bubbles. These bubbles rupture under pressure, creating tiny vacuums that act like suction cups to stick the note to a surface. The notes will continue to stick after multiple uses until all the bubbles have been burst so no further vacuums can form.



A microscopic image of the adhesive part of a Post-It note

BEGINNINGS: THE MAKING OF THE MODERN COSMOS

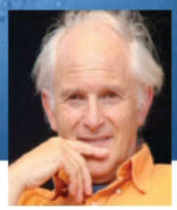
STARMUS

22 | 27 September
Abama Golf & Spa Resort
Tenerife, Canary Islands, Spain

Starmus Festival 2014

Stephen Hawking
Theoretical Physicist & Cosmologist

Robert Wilson
Nobel Prize Winner



Harold Kroto
Nobel Prize Winner

Richard Dawkins
Ethologist & Evolutionary Biologist

Brian May
Astrophysicist, musician, singer and songwriter

Charles Duke
Apollo Astronaut

Edgar Mitchell
Apollo Astronaut

Harrison Schmitt
Apollo Astronaut

Alexei Leonov
Soviet/Russian Cosmonaut

Viktor Savinykh
Russian Cosmonaut

Sergei Krikalev
Russian Cosmonaut

Yuri Baturin
Russian Cosmonaut

Chris Lintott
Astrophysicist and presenter of BBC Sky at Night

Kateriana Harvati
Professor of Paleoanthropology

Robert Williams
Astrophysicist

Jill Tarter
Astronomer & SETI Research

Sonic Universe Concert

"An exceptional concert of modern music for your enjoyment. A message of harmony sent into space that will reverberate to the edges of the Universe. Sounds and emotions entwined forever in this unique experience".

Rick Wakeman & Brian May

Following on from the huge success of the first Starmus "50 years in space" festival in Tenerife in June, 2011, which featured keynote presentations from Neil Armstrong, Buzz Aldrin, Jim Lovell, Alexei Leonov, Richard Dawkins, Kip Thorne and George Smoot. We are very pleased to announce the second Starmus 2014 Festival, the finest combination of astronomy, science, art and music to be found anywhere in the world at this time.

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"Seven of the ten longest bridges in the world are located in China, with most of these being rail bridges"

How bridges are built

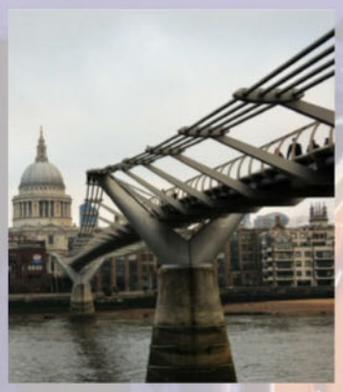
The design and technology behind these fundamental structures

All over the globe, bridges come in many shapes and sizes. The humble structure was born by simply balancing a horizontal beam across two pillars. However, as demand grew, wider gaps needed to be crossed and more weight had to be carried. This created the need for arches. Utilised by the Ancient Romans, the arch shape could hold massive amounts of weight and was a revelation in creating larger and stronger bridges. However, arches could only reach a certain length. To cross larger expanses, even longer bridges have to be constructed. These are called suspension bridges. These work using a combination of compression and tension forces that run through a cable system. The road or 'deck' is laid out across these cables, which are strung together with the correct balance of the two forces so it won't buckle or snap under pressure. On most suspension bridges, a tower is placed at either end to take the strain and weight. Iconic examples of these bridges include the Golden Gate Bridge in San Francisco and England's Humber Bridge. Away from the road, bridges are also used for rail and water transport. These bridges are often even longer and stronger as they have to ferry water or huge freight and passenger trains or ferries over vast distances. Seven of the ten longest bridges in the world are located in China, with most of these being rail bridges. As technology and engineering improves, even-more expansive bridges could be in the pipeline. There has been talk of a bridge between England and France and a crossing through the Strait of Gibraltar connecting Europe and Africa. Although it may seem far-fetched, the 16-kilometre (ten-mile) Øresund Bridge that links Denmark and Sweden has demonstrated that cross-country bridges can be constructed successfully.

The Millennium Bridge

Why this famous London structure started swaying

When a new bridge is designed and built, it is essential that all of its construction calculations are absolutely correct. If they are even slightly out, the entire structure could become perilously unstable. Take the Millennium Bridge in London, for instance. Opened in 2000, the bridge experienced sudden and very dangerous sideways movements after the huge crowds who crossed it caused it to sway under the pressure. The eventual solution was to use 91 dampeners underneath the bridge, which absorbed the kinetic energy of the pedestrians' movement and prevented it from wobbling. It reopened fully fixed in 2002 but at a cost of over £5 million ($8 million). An expensive mistake!



Compression and tension
The sheer length of suspension bridges means many forces act upon it. The bridge's job is to balance the forces and transfer them to a stronger area that can handle the pressure.

Deck
The deck can be made to suit road, rail or even water. It is strengthened by a truss that runs underneath the highway, allowing heavier weights to be transported across.

"When a new bridge is made, it is essential that all of its construction calculations are correct. If they are even slightly out, the structure could become unstable"

HEAD 2 HEAD
LONGEST BRIDGES

1. LONG

Rio-Niteroi Bridge

This 13km (8mi) bridge connects Rio de Janeiro and Niterói in Brazil and saves residents a 100km (62mi) commute.

2. LONGER

Lake Pontchartrain Causeway

Many bridges cross the US lake but the most gigantic of them is a huge 39km (24mi) long.

3. LONGEST

Burapha Withi Expressway

This six-lane raised highway in Thailand is the longest road bridge in the world at a sprawling 55km (34mi) long.

DID YOU KNOW? *The world's first-ever iron bridge was officially opened in Shropshire, England in 1781*

The key features of a suspension bridge

How the world's most impressive bridges work

Tower

The strongest areas are the towers at each end. The cables transfer the tension and compression forces to them so the bridge does not buckle or snap under the strain.

Length

The longest suspension bridge in the world is the Akashi Kaikyo Bridge. The 'cable-stayed' technique allows for longer bridge building using more towers to spread out the tension and compression.

Foundations

The cables are anchored into the foundations of the towers. This strong system absorbs the forces acting upon the bridge and diverts the pressure away from the weaker sections.

The statistics...

Akashi Kaikyo Bridge

Year completed: 1998

Years taken to build: 10

Bridge type: three-span suspension bridge

Length: 3,911m

Height: 283m

Deck: Six-lane road

Wind resistance: Up to 290km/h

Earthquake resistance: Magnitude 8.5 Richter

Steel used: 180,000 tons

Concrete used: 1.4 million m^3

Types of bridge

The many ways to bridge and cross a gap

Arch

One of the oldest methods of bridge building, the arch bridge is made by compressing stone, steel and concrete with the finished arch working as a wind bracer. They can range from small brick designs to tall and extensive metal constructions.

Suspension

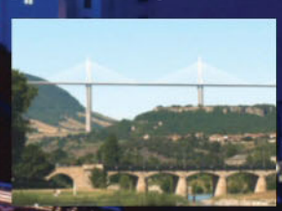
This type of bridge is made of steel plates and cables. Suspension bridges use a combination of tension and compression, which is carried by the cables to towers at either end. The cables transfer the weight to the towers. Their light weight allows them to span long distances.

Beam

Made out of wood or iron, beam bridges are the simplest type of bridge construction. The weight is put on two support girders on either side of the crossing. The earliest examples of beam bridges came in the form of humble logs or tree trunks across streams and rivers.

Cable-stayed

The cable-stayed bridge is one of the most common in contemporary bridge building. They have one or more towers, each of which uses vertical compression to move the forces from the cables through to the foundations, reducing the strain and stress on each part of the bridge.



Bascule

Also known as a drawbridge, it ranges in size from a medieval feature to larger structures like Tower Bridge. Usually powered by a counterweight and winch, similar designs include a vertical-lift bridge that rises straight up and a swing bridge that can pivot horizontally to open up.

"The breathing tube will push air into your lungs, where it can be circulated around the body"

Medical ventilators

How these breathing machines perform their life-saving task

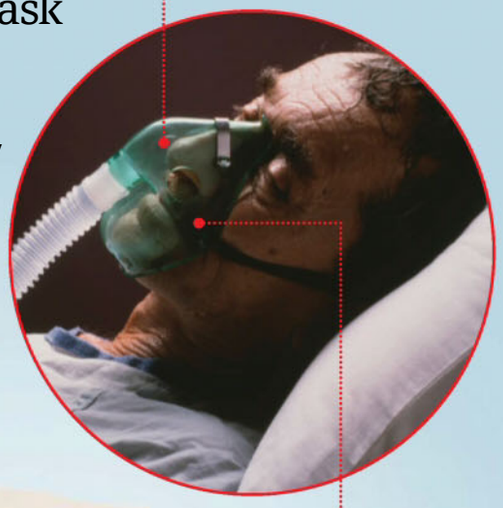
Breathing is one of the most natural things in the world. It's the first thing we do when we're born and we go on doing that automatically for the rest of our lives. But sometimes people need assistance with their breathing if they have respiratory issues or are under anaesthetic during an operation.

This is where the ventilator comes in. It is a machine that contains oxygen and air, which is pumped through a tube, either into your mouth or into a surgical hole in your neck, by increasing pressure in the machine, pushing the air into the lower pressure area of your lungs.

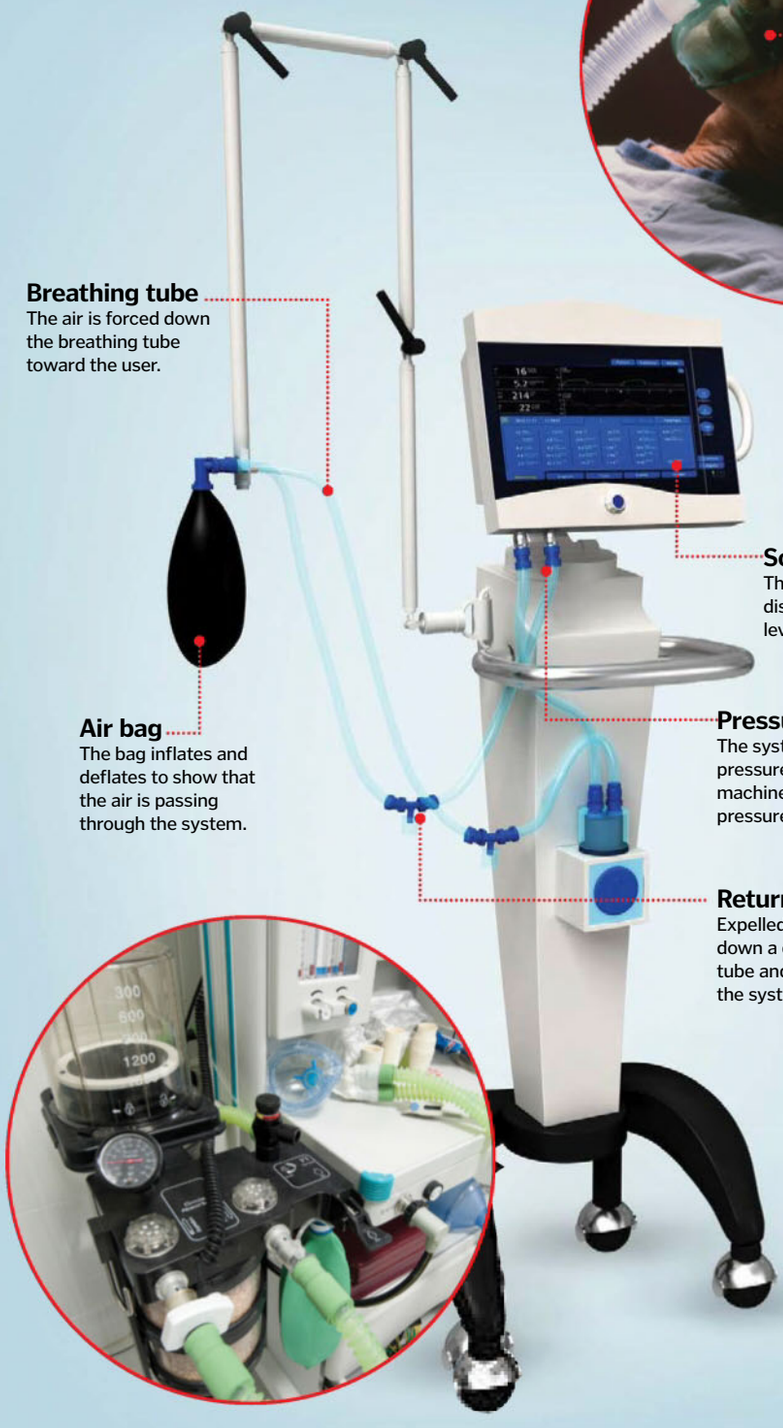
The second option is used for people who will need to be on the ventilator for longer as it is more comfortable and may allow the user to talk. The breathing tube will push air into your lungs, where it can be circulated around the body, and will also take the leftover carbon dioxide out of your body. This is called the endotracheal tube as it goes into the trachea or windpipe. It stays on your face by a strap that goes around your head. Settings on the ventilator regulate how often air is pumped into the lungs every minute, although the user can increase this if they are feeling short of breath.

Inside a ventilator

How this machine pumps essential air into your body



Breathing mask
A mask is fitted over the mouth and nose so the air cannot escape.



Breathing tube
The air is forced down the breathing tube toward the user.

Artificial breathing
The air gets pushed from the pressurised mask into your mouth, nose and travels to your lungs.

Screen
This provides a visual display of the pressure levels in the system.

Air bag
The bag inflates and deflates to show that the air is passing through the system.

Pressure change
The system increases pressure inside the machine, creating a pressure imbalance.

Return
Expelled air travels down a different tube and back into the system.

The original respirator

Respirators have been around since the late 1920s when Philip Drinker and Louis Agassiz Shaw created the first widely-used negative pressure ventilator, which was more commonly known as the iron lung. It was a heavy machine, powered by vacuum cleaners and run using an electric motor. It used a pump to force air into the lungs and then draw it out again by decreasing pressure.

John Haven Emerson added a sliding tray so the user could be pushed in and out of the machine more easily, as well as windows along the side so attendants could reach in and adjust the patient. This design halved the cost of the original machine, which had been the same as a house.

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"It sends a signal to the computer, which translates that information into cursor movement"

Inside a computer mouse

How did one little invention help us point and click?

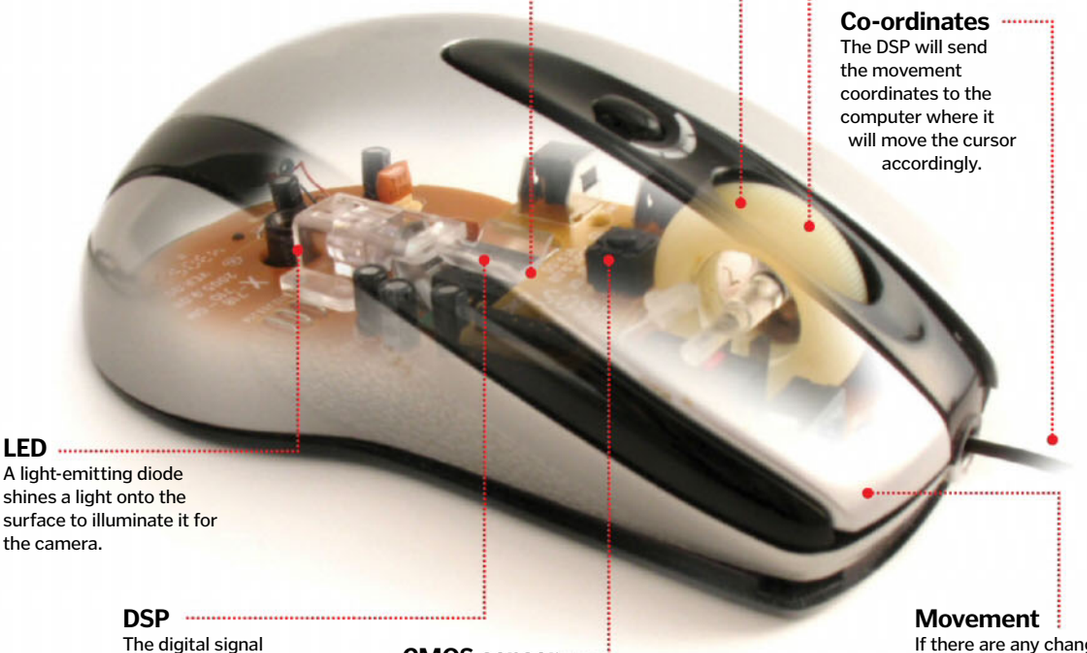
Chances are if you are using a mouse to navigate around your computer that it's an optical mouse. It was invented in 1980 and has pretty much completely replaced the ball-guided mouse. An optical mouse works using microscopic imaging technology. First, a tiny camera inside the mouse photographs your desk or mousemat. The red glow you can see if you turn it upside down is a red light-emitting diode (LED) inside that projects light onto the surface. When the light hits the surface and bounces back into the mouse it hits a complementary metal-oxide semiconductor (CMOS). This sends a message to a digital signal processor (DSP), which closely analyses changes in the pattern of the surface. Once it registers a movement, it sends a signal to the computer, which translates that information into a cursor movement. These adjustments happen hundreds of times every second, so it follows your hand movements in extreme detail.

On top of the mouse is usually either a wheel or a tiny rubber ball. These use the same technology as early ball-guided mice. Rotating the wheel or ball with your finger moves a couple of rollers. These are wired up to a processor which analyses how much each roller has moved and allows you to move a web page or document up and down or, with the ball-topped mouse, side to side.

These developments have greatly helped day-to-day computing, making navigating around the screen much easier than before and revolutionising PC gaming by enabling millimetre-perfect movement.

Inside an optical mouse

What goes on inside your mouse to help you work, rest and play?



Camera
A tiny camera sits in the middle of the mouse, pointing downward and taking 1,500 pictures of the surface below every second.

Wheel
Many mice also feature a wheel on top for additional ease of navigation.

Up and down
This provides vertical movement, meaning you can scroll up and down a web page or document.

Co-ordinates
The DSP will send the movement coordinates to the computer where it will move the cursor accordingly.

LED
A light-emitting diode shines a light onto the surface to illuminate it for the camera.

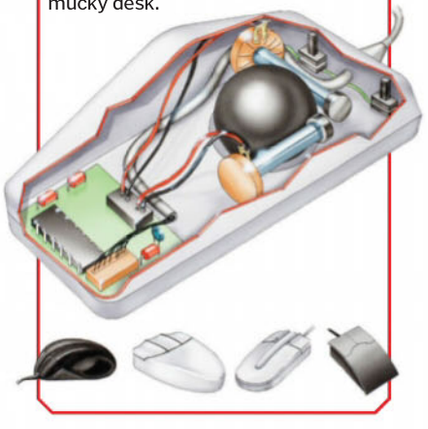
DSP
The digital signal processor looks at the images and notices if there have been any changes in the surface below the mouse.

CMOS sensor
A complementary metal-oxide semiconductor receives the light that has bounced off the surface and sends it for processing.

Movement
If there are any changes in the pattern below the mouse, the sensors will pick that up and work out how much it has moved.

How the roller-ball mouse worked

The roller-ball mouse was the standard design for years before the optical mouse came along, but what went on inside that casing? As you moved your hand around, the ball rolls too. The ball touched two rollers, one behind and one to the side of the ball to detect vertical and horizontal motion respectively. Wires attached the rollers to a circuit board, transmitting movement data. This data was used to move the cursor around the screen with a greater degree of accuracy than the earlier wheeled mouse. The main downside of the roller ball mouse wasn't anything to do with the electronics. Dirt and grime from the surface it was on would collect inside the hole the ball emerged from, making it stick. The new optical mouse does provide a greater degree of accuracy, but its main advantage over the roller ball is that it won't stick if you have a mucky desk.



DID YOU KNOW? *Microsoft's acquisition of Skype cost the company a cool £5bn ($8.5bn)*

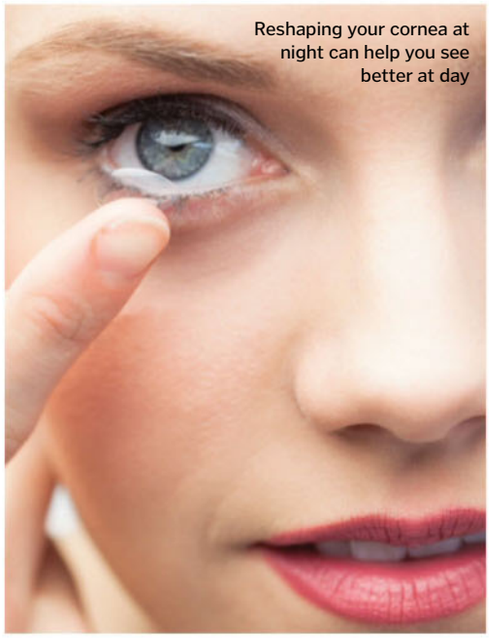
A cornea-reshaping lens

Sleeping with this special contact lens can correct near-sightedness

Sick of spectacles? Can't handle contact lenses? There's now a way to correct your vision; orthokeratology. This method involves a type of gas-permeable contact lens that reshapes your cornea while you sleep. When you wake up in the morning, you remove the lenses and your vision is 20/20 for the day. This will last for a few days until your eyes' corneas return to their natural shape and prescription, but you can repeat the process.

The procedure, which is also known as corneal refractive therapy, is most effective for people with mild myopia (near-sightedness). It is also used to treat hyperopia (far-sightedness) and astigmatism. 'Ortho-K' can also help correct or prevent the onset of presbyopia, where the eye's ability to focus on close objects is diminished. As well as being a day-to-day treatment, it can be used to slow the onset of near-sightedness in children.

Orthokeratology is primarily designed for people who do not qualify for laser eye surgery. The reshaping of the cornea is only temporary, so there is very little risk for the eye. The surface of the eye is measured by a corneal topographer, which maps the cornea so the corrective lens can be moulded in the right shape. In some patients 20/20 vision isn't possible, but 20/40 – usually the legal limit for diving – is the aim point for the majority of procedures.



Reshaping your cornea at night can help you see better at day

Corneal refractive therapy

What happens to your eye overnight

Diagnosis

Your near or far-sightedness may be due to your cornea being the wrong shape. This is where orthokeratology comes in.

Fitting the lens

The lens is put onto your eye just like a standard contact lens. You wear it as you snooze and take it out in the morning.

Correction

The cornea in each eye will adjust into a new mould overnight to give you better eyesight. It is a painless process.

The next day

The following morning your sight will have improved. Lasting for a few days, the process can be repeated for extended effect.

The Skype Translator

The beginning of the end for language classes?

The immensely popular internet phone and messaging service Skype has approximately 300 million monthly global users. For its next trick, the Microsoft-owned service plans to break down language barriers by automatically translating multilingual voice calls. This bold claim is backed up by some impressive technology.

Using a combination of existing speech recognition, text-to-speech and machine-translation technology, the program will translate any word you utter into a text format of the desired language. Current translation programs use a similar system but can currently only work if they are in the same room. The new Skype software will look to change that, allowing for fully translated international calls.

One stumbling block is the vast amount of different dialects and accents used all over the globe. Because of this, some say there will always be a need for human interpreters as computers can never be completely accurate to detect subtle language variations.

The translator is scheduled to be released on Windows 8 by the end of the year, while other companies such as Lexifone, Google and NTT DoCoMo are working on a similar system. Skype Translator is intended to help in all areas from education to business to international relations. Or maybe just to help you and your German exchange buddy communicate better.

The Skype Translator may revolutionise real-time communication online

AMAZING MIGRATIONS

Covering thousands of miles across land and sea, migrations are one of nature's true tests of endurance

Migration stats...

16,000km (10,000mi)

Leatherback sea turtle migration

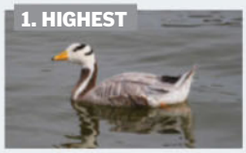
For some species, a migration is a habitual journey every year, but for others it is the never-ending voyage of a lifetime. The key element that links every type of migration is the instinct to survive.

Animals will move location in order to position themselves in the best place for their needs. This could be a move with the seasons to escape the cold weather, like the swallows that leave UK shores for the balmier African climate each winter. Similarly, some animals will move where the food goes, or for other instincts such as to breed. Others will make the journey to safety to give birth, like humpback whales that migrate to calving grounds in the winter, and some migrate to raise young, escape overcrowding or to fulfil a biological need like moulting. Whatever the reason for such a journey, necessity is at the core.

But how do they know where to go and when to leave? Each species has its own cues. For example, birds that leave the UK in winter can tell it's time to migrate when the days start to shorten and the nights get chillier. These seasonal cues also help them find their way. Visual clues, such as the position of the Sun, with other sensory clues like scent and sound of their destination alongside detection of Earth's magnetic field help all kinds of animals to navigate.

Animals can survive such journeys by fattening up in preparation, travelling in large groups and by hitching a lift on currents and winds. Migration is closely linked to seasonal changes and weather patterns. When things go wrong, this can affect the rest of the ecosystem, which relies on the migrating species' arrival. For example, due to climate change, some bird species are migrating earlier and departing later. This means that when they arrive too early there is not enough food to go around, and so their chicks suffer as a result. In turn, there are fewer of these birds for their predators to eat, and so on as the effect ripples through the ecosystem.

1. HIGHEST



Bar-headed goose
These geese can reach 6,300m (20,669ft) in altitude on their mammoth migration over the Himalayas.

2. LONGEST

Blue whale
At over 30m (98ft) long, the blue whale is naturally the longest migrating animal on Earth, as it's the biggest animal in history.

3. LARGEST

Plankton
The daily vertical migration of plankton from deep water to the surface is the largest migration on Earth in terms of biomass.

DID YOU KNOW? *Every autumn, millions of red crabs migrate to spawn at the coast of Christmas Island in the Indian Ocean*

The Serengeti's great migration

Year on year, huge herds of wildebeest, zebra, gazelle, eland and impala migrate around the Serengeti in search of fresh water sources and lush grazing areas

The herds spend January to March spread out and grazing the lush short-grass plains of the South Serengeti. The females calf in two to three weeks around February and March before starting their long journey north through Seronera as they head toward the Western Corridor in April and May.

June sees the vast herds split, as some cross the Grumeti River and move into the Grumeti Reserve, while others choose to head north. Over the summer months the herds gradually reunite in the northern part of the Serengeti National Park and spread out over the border into Kenya's Maasai Mara.

The wildebeest spend October in the far north of the Serengeti and into Maasai Mara before heading south, down the eastern side of the Serengeti National Park. As December arrives, the herds are just in time for the rains and graze on the lush southern plains once more.

Migration stats...

2 million
Animals migrate across the Serengeti every year

How birds navigate

Birds sure don't need maps – they use incredible senses to find their way

Sun compass
Some birds, such as homing pigeons, use the Sun's position as a navigational cue. This is helped by their circadian rhythm (or 'internal clock') as the Sun tracks across the sky.

Star compass
Night migrations made by birds use the stars to find their way. This isn't an innate behaviour, so they birds must learn their north-south orientation by observing stars at a young age.

Odour map
A bird's sense of smell can put it on the right path. The scents of its home range can imprint a 'map' that can guide it back to the nest.

Magnetic map
Another theory is that many birds may rely on Earth's magnetic field to find their way. The strength of this field increases the further away the bird gets from the equator.

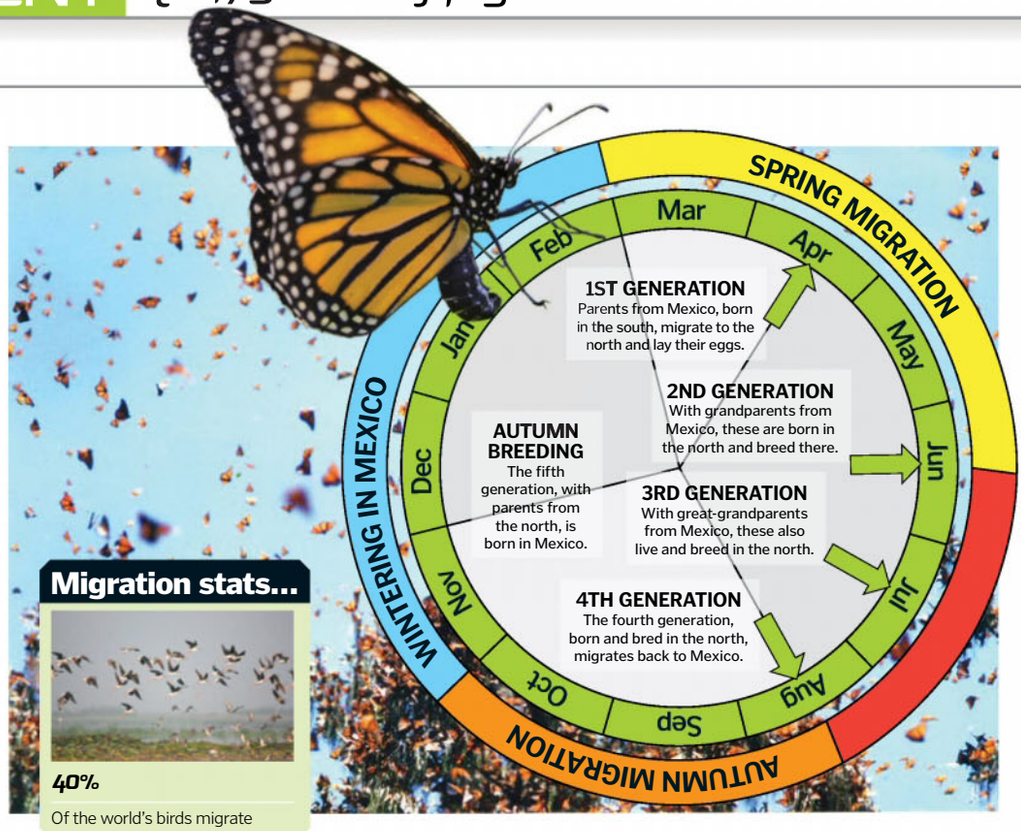
Magnetic compass
Migratory birds collect magnetic-field information through specialised receptors within their eyes. These receptors help them to distinguish north and south with no other visual clues.

"As the seasons begin to turn, the birds begin their 35,000-kilometre (21,750-mile) flight south"

Monarch butterfly

The monarch butterfly makes its home in the northern United States and Canada, but every year millions of them embark on a 4,828-kilometre (3,000-mile) journey south to the hills of central Mexico to avoid the harsh winter weather. Here they rest on tree branches in incredibly dense gatherings as they hibernate for four months.

What is incredible about this migration is that in summer, a monarch butterfly only lives up to six weeks. One generation migrates south, but it's that generation's grandchildren that migrate back north in the spring. Yet the butterflies always know where to go, sometimes even returning to the exact same trees their ancestors used.



Migration stats...

40%

Of the world's birds migrate

Arctic tern

Every year, these little birds take to the wing to cover a mammoth distance, practically from pole to pole.

During the northern hemisphere summer, Arctic terns breed in colonies in Arctic and sub-Arctic regions of Europe, Asia and North America. 24-hour sunlight allows them to hunt and feed their chicks around the clock.

As the seasons begin to turn, these birds begin their flight south. They begin their 35,000-kilometre (21,750-mile) flight to the Southern Ocean where they will stay from November to March before returning to the Arctic to breed in the spring. This allows these birds access to 24-hour sunlight for eight months of the year!

Migration stats...

2.4mn km (1.5mn mi) OR equivalent to 3 trips to the Moon

The distance arctic terns could travel in a lifetime

4,800km

FURTHEST OVERLAND MIGRATION

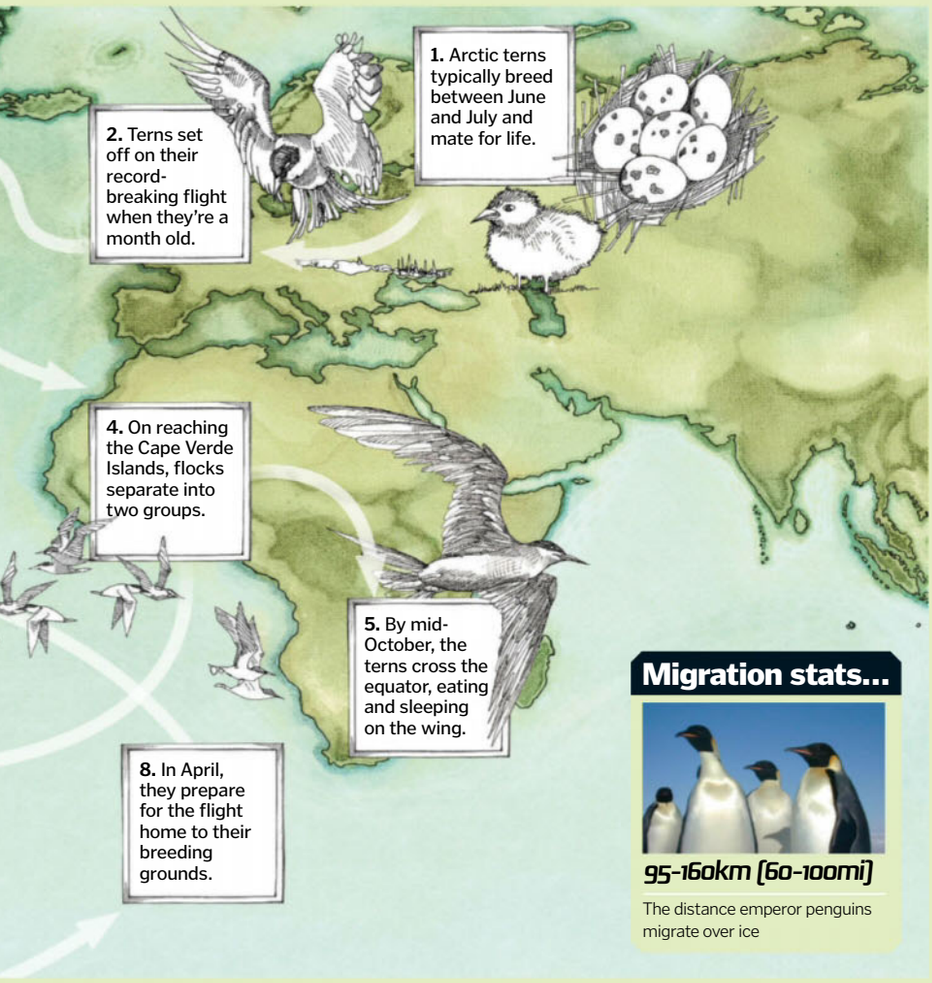
Porcupine caribou hold the record for their incredibly long migration of up to 4,800km (2,983mi) per year across the frozen tundra in North America.

DID YOU KNOW? *Wandering albatrosses circumnavigate the globe as they migrate after the breeding season*

Salmon

The salmon's story begins with eggs laid in shallow freshwater streams, miles inland. As the young fish hatch and grow, they move downstream until they reach a river mouth. These hardy fish adapt from living in fresh water to living in salt water and embark on an ocean-going journey as adult salmon to feed at sea.

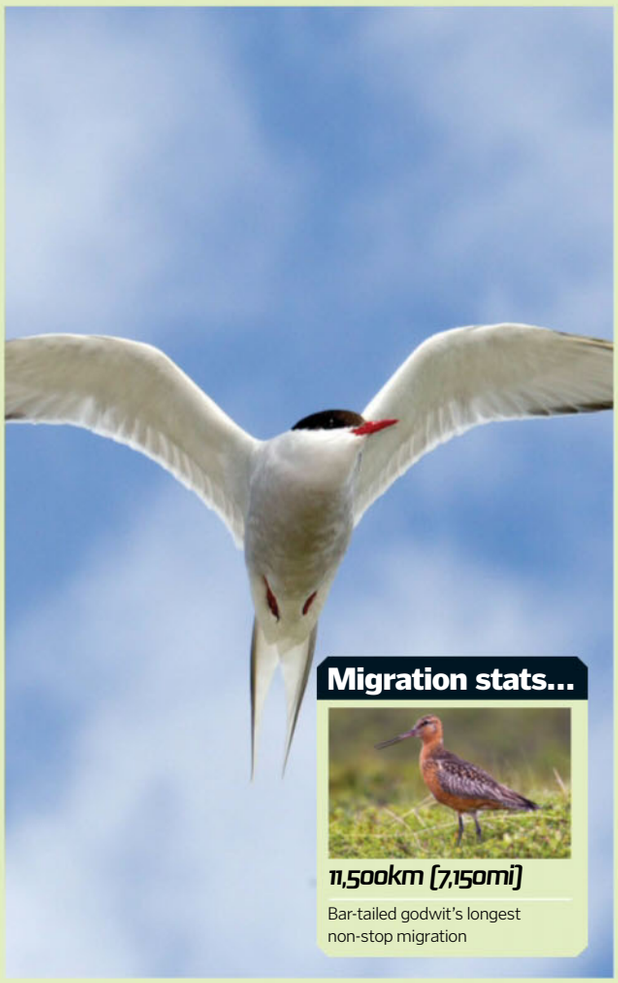
After a few years of fattening up, adult salmon make the staggering journey back to their home rivers to breed. They can home in on the exact location they were born using Earth's magnetic field, the imprint of their river's 'scent' and pheromones secreted into the water by other salmon.



Migration stats...

95-160km (60-100mi)

The distance emperor penguins migrate over ice



Migration stats...

11,500km (7,150mi)

Bar-tailed godwit's longest non-stop migration

"Yellowstone National Park has over 500 geysers, more than any other place in the world"

What is a geyser?

Discover the underground secrets of Earth's geothermal activity

A geyser is a rare hot spring that erupts in a violent display of water and steam. The key to this amazing phenomenon is a mixture of heat and constriction.

The discharge from a geyser is essentially geothermal heat escaping from the ground. Rather then having a constant flow of water like a conventional hot spring, they have a complex 'plumbing' system that periodically releases the steam. Constrictions near the surface are created by the dissolution of silicon dioxide (silica) from the igneous rock rhyolite by hot water. This creates sinter, which forms the characteristic cone of a geyser.

Water from rain and snow make their way into the hot porous rock created from a deep underground magma chamber. This superheats and evaporates the water to create steam, which bursts out into the air as more and more pressure is added onto the near-surface constrictions. The steam takes up to 1,600 times more space than the original volume of water and is over 100 degrees Celsius (212 degrees Fahrenheit). On some geysers, the pressure can be diverted through various side channels, as well as the major release outlet. There are two types of geyser: cone and fountain. The former type is named due to the shape of the formation of the spout hole while the latter type is a flat pool of water.

Human activity can affect geysers. In the past there used to be two large geyser fields at Beowawe and Steamboat Springs in Nevada but they were destroyed by the construction of geothermal power plants, which took away the heat needed to power them. A similar occurrence happened in New Zealand when a hydroelectric dam flooded the geyser area.

Yellowstone National Park in Wyoming, USA, has over 500 geysers, more than any other area in the world. This includes the famous Old Faithful, which erupts on an average of every 90 minutes, and the world's largest, Steamboat Geyser, that blasts water up to 90 metres (300 feet) into the air! Don't make a journey especially to see it, though; it has had less than ten major eruptions in the last 20 years! Following an eruption, water gradually flows back into the hole on the surface and the process starts all over again.

Geyser wannabes

Hot spring Japanese macaques enjoying a hot spring bath.

Fumarole: Fumaroles on the Fourpeaked Glacier in Alaska.

Mudpot: A mudpot in Yellowstone National Park.

ON THE MAP

Geyser hotspots

Geyser centres around the globe

1. Valley of Geysers, Russia
2. Yellowstone National Park, USA
3. Taupo Volcanic Zone, New Zealand
4. Haukadalur, Iceland
5. El Tatio, Chile

STRANGE BUT TRUE
GUSHING FACT

How many geysers are there on Earth?

A 1,000 **B** 1 million **C** 10 million

Answer:
As geysers require such a particular set of geothermal conditions to exist, they are surprisingly very few and far between. They are predominantly based in volcanic areas. Approximately 1,000 are known to be active on Earth with a small number of dormant and extinct geysers as well.

DID YOU KNOW? *Famous geyser Old Faithful's eruptions get less frequent when there is a reduced water supply during droughts*

Inside a geyser

Ever wondered where the burst of steam comes from?

Surface eruption
The whole process concludes with the launch of a plume of steam into the air that can reach heights of 90m (300ft).

Side channel
The steam forces its way through many channels so away from the main geyser, there can be several side vents and springs.

Heated water
After prolonged exposure to the magma chamber, the water becomes superheated.

Water flow
Water from rain, ice and snow flows forces its way through the ground, creating cracks in the rock.

Steam chambers
The water gets so hot it eventually evaporates, creating pockets of steam, which expand through the system.

Magma chamber
Heat from the underground geothermal activity rises up and raises the temperature of the water.

Melting rock
A combination of intense heat and groundwater creates cracks in the rock, forming pockets of groundwater.

Space geysers

Not just limited to Earth, extraterrestrial geysers have also been witnessed. Io, a moon of Jupiter, has been shown to have volcanic features including surface vents that launch sulphur dioxide into the atmosphere. The largest two are known as Prometheus and Pele, which can discharge the sulphur 300 kilometres (186 miles) into the air! Cold geysers known as cryovolcanoes have also been found on the Saturnine moon of Enceladus. These are similar to the geysers on Earth and release water vapour. Jokingly nicknamed 'Cold Faithful', these underground springs go a long way to proving the theory that a lake of liquid water lies under Enceladus' surface. Geothermal activity is also common on Mars with carbon dioxide emissions frequent in the Martian spring when a warmer temperature allows the gas to discharge.

ABOVE Prometheus can be seen right in the centre of the image while the gas on the top of Io is discharge from another geyser

"As the floods washed or evaporated away, they left these quartz slabs scattered around the plains"

Petrified forests

Perfectly preserved 225-million-year-old trees

All over the world you can find strange-looking slabs of wood, strewn across a barren landscape. However, these haven't actually been wooden for millions of years.

Around 225 million years ago, prehistoric trees fell into rivers, where they were quickly covered with a layer of sediment, silt and mud. This rapidly formed a tight wrap around the trunk, cutting off any oxygen that would have rotted the wood. Over time, minerals were absorbed into the wood, including silica. This material is known for its crystallising properties and as the log slowly rotted away over a period of many centuries, the silica replaced it, forming stunning crystal representations of the original material's shape and turning the wooden logs into quartz slabs.

As the floods washed or evaporated away, they left these quartz slabs scattered around the plains. Wind and sand erosion continued to batter these slabs until the last few pieces of organic material was stripped away, leaving stunning quartz blocks dotted around barren, arid landscapes around the world.

Petrified wood tends to be found in areas near volcanoes. This is because the silica, which is key to the production of the stunning crystals, usually comes from ash spewed out by an erupting volcano. Most petrified forests are protected areas, so you are allowed to go and view these incredible natural phenomena, but unfortunately you can't take any of it home for your mantelpiece.

Why do plants rot?

Once a plant dies, it will start to rot (decompose). They decay because microorganisms release enzymes that break down compounds for digestion. Bacteria and fungi – the main decomposers – depend on moisture and oxygen for their respiration. When both are absent from the process, the microorganisms work much slower and, in the case of petrified wood, rotting takes up to millions of years.

Notable petrified forests

The Petrified Forest National Park near Holbrook, Arizona, is one of the biggest and most impressive petrified forests in the world. It houses nearly a dozen different types of petrified wood, ranging from conifers to ferns. It grew to today's impressive size due to the large river network upstream of the site.

Argentina's Petrified Forest National Monument is a jaw-dropping demonstration of the changes the planet has undergone in its lifetime. Before the vast Andes mountain range even existed, vegetation was everywhere, some trees reaching 100m (328ft) high. Then, geological shift created the Andes and accompanying volcanoes, burying the plant life in ash, creating an amazing petrified forest.

The petrified forest near Maadi, around 30 kilometres (19 miles) from Cairo in Egypt is quite young, the logs appearing around 35 million years ago. This was a time of geological upheaval as the Red Sea formed from the separation of tectonic plates. The forest spans about six kilometres (four miles) and was declared a protectorate in 1989 so it could be officially preserved by the Egyptian government.

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An animal in crisis
In eastern Africa, poachers use automatic weapons to slaughter endangered rhinos. The animals are shot and the horns are hacked away, tearing deep into the rhinos' flesh with the rhino left to die.

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"Blood vessels also feature valves, which help prevent blood from flowing backward due to gravity"

Why do giraffes have such long necks?

The anatomy of Earth's tallest animal explained

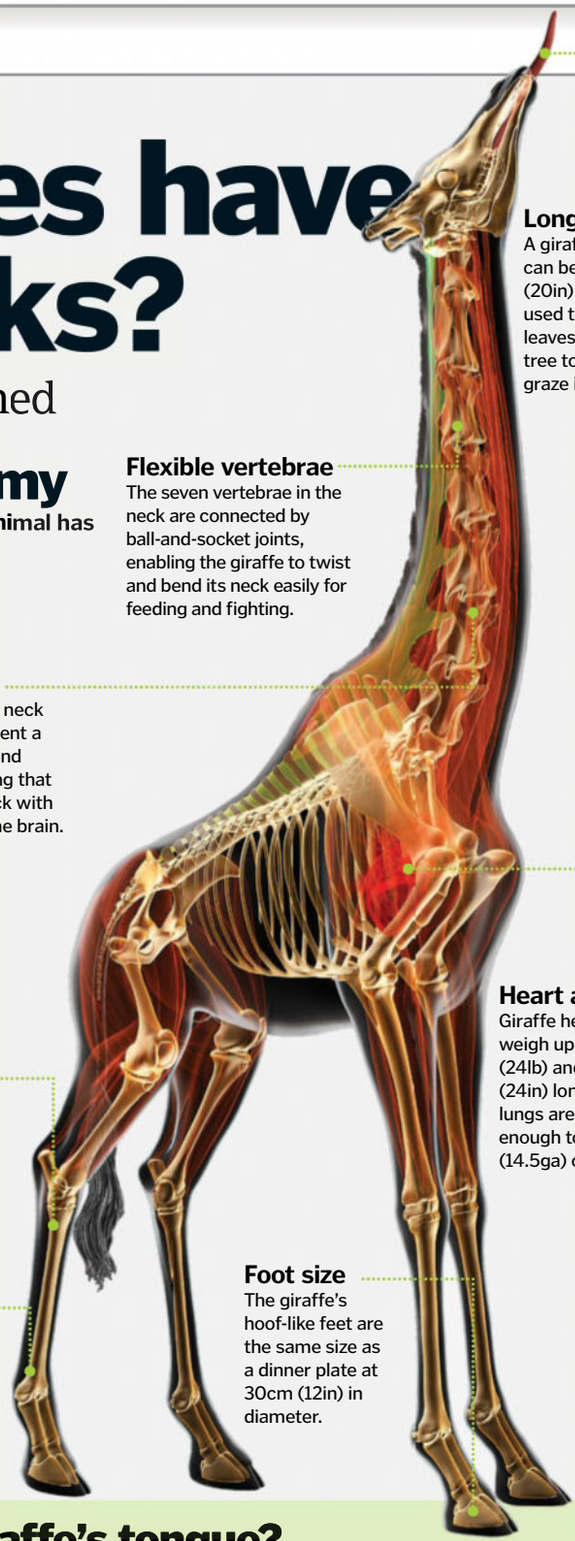
Towering above the grasslands and savannah plains, these gentle giants are the tallest land mammals on our planet. Giraffes can grow up to 5.8 metres (19 feet) in height, even their legs alone are taller than most humans at an incredible 1.8 metres (six feet) high. However, it's their remarkable necks that really bolster this animal's stature and hold the secret to their survival in the wild.

Although a giraffe's neck has a rigid, muscular appearance, it is very flexible. The vertebrae inside the neck are fixed together by ball-and-socket joints, similar to a human's shoulder, which gives them a great range of motion. They also have a unique cardiovascular system that compensates for their long necks and helps ensure an adequate blood flow to their brain at all times. Blood vessels inside the neck feature valves and this - along with a large heart and lungs - help to prevent blood from flowing backward due to gravity.

A giraffe's flexible neck puts it at a great advantage when it comes to grazing. Not only can this animal reach tall tree tops for their preferred food, acacia leaves, but with their legs splayed, they are also able to graze on low-lying foliage. Male giraffes also frequently use their necks in powerful fighting displays to ward off the competition during the mating season, which involves swinging their necks into their rivals during battle.

Giraffe anatomy

Take a closer look at how this animal has evolved to survive in the wild



Long tongue
A giraffe's tongue can be 50cm (20in) long and is used to help strip leaves from the tree tops as they graze in the wild.

Flexible vertebrae
The seven vertebrae in the neck are connected by ball-and-socket joints, enabling the giraffe to twist and bend its neck easily for feeding and fighting.

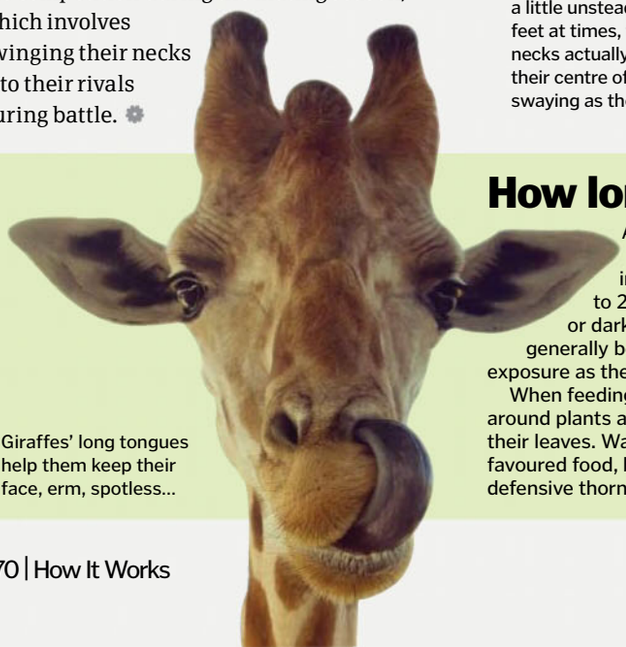
Blood circulation
Blood vessels inside the neck have valves to help prevent a head rush as giraffes bend down, as well as ensuring that blood does not backtrack with gravity as it travels to the brain.

Heart and lungs
Giraffe hearts can weigh up to 11kg (24lb) and are 60cm (24in) long. Their lungs are also large enough to hold up 55l (14.5ga) of air.

Leg length
Although the back legs appear longer, they are same length as the front at 1.8m (6ft). The tight skin around the legs also helps blood circulate better.

Foot size
The giraffe's hoof-like feet are the same size as a dinner plate at 30cm (12in) in diameter.

Stability
Although giraffes can look a little unsteady on their feet at times, their heavy necks actually help guide their centre of gravity by swaying as they walk.



Giraffes' long tongues help them keep their face, erm, spotless...

How long is a giraffe's tongue?

A giraffe's tongue isn't as long as their necks but it's still an impressive 45 to 50 centimetres (18 to 20 inches) in length. It is also black or dark purple in appearance, which is generally believed to protect it from sun exposure as they graze.

When feeding, a giraffe will wrap its tongue around plants and shoots in order to strip them of their leaves. Water-rich acacia leaves are a favoured food, but these trees have prickly defensive thorns, which prevent most herbivores from devouring them. However, the giraffe's dexterous tongue has thick and resilient papillae, which helps to protect it as it reaches around the thorns to get to the food. Their thick saliva is also thought to cover any prickly thorns that are stripped in order to protect the giraffe's tongue and mouth from harm.

Aside from using their tongues to help them consume up to 34 kilograms (75 pounds) of food on a daily basis, giraffes will also frequently use them to clean out their own ears and eyes. That's quite the party trick.

Cumulus
These small clouds that look like bits of cotton wool don't ever soar above 1,980m (6,500ft) in the sky, which is still higher than some others.

Altostratus
A blue or greyish cloud formation, altostratus clouds are found at a height of between 2,130m (7,000ft) to 5,500m (18,000ft).

Cirrus
Found at altitudes of up to a lofty 12,200m (40,000ft), cirrus clouds take on and reflect the red colour of the sunset you see at dusk.

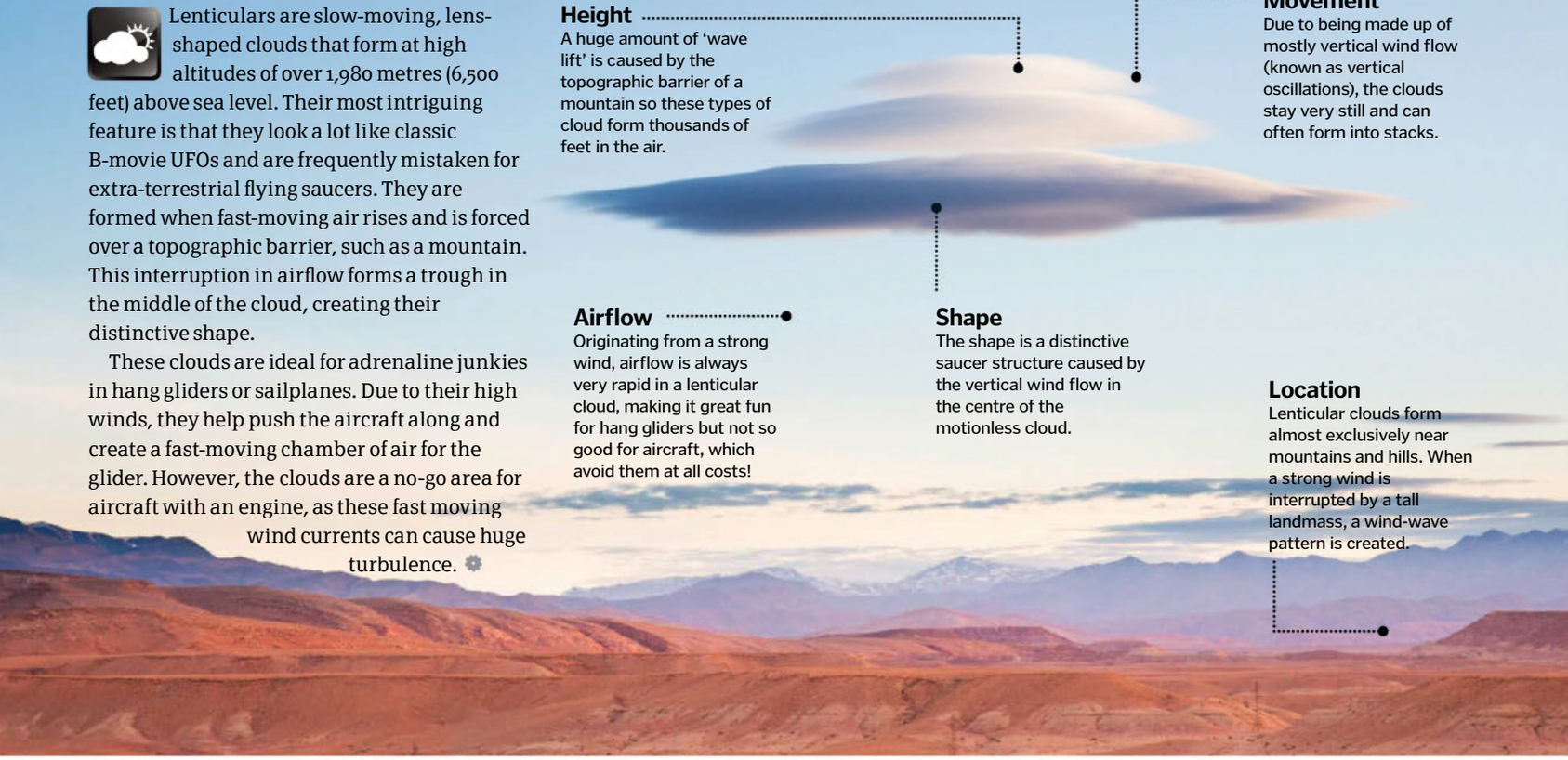
DID YOU KNOW? *When a 3D print creates an illusion of depth, it is known as lenticular printing*

What are lenticular clouds?

Explore the cloud formations that look suspiciously like UFOs

Lenticulars are slow-moving, lens-shaped clouds that form at high altitudes of over 1,980 metres (6,500 feet) above sea level. Their most intriguing feature is that they look a lot like classic B-movie UFOs and are frequently mistaken for extra-terrestrial flying saucers. They are formed when fast-moving air rises and is forced over a topographic barrier, such as a mountain. This interruption in airflow forms a trough in the middle of the cloud, creating their distinctive shape.

These clouds are ideal for adrenaline junkies in hang gliders or sailplanes. Due to their high winds, they help push the aircraft along and create a fast-moving chamber of air for the glider. However, the clouds are a no-go area for aircraft with an engine, as these fast moving wind currents can cause huge turbulence.



Height
A huge amount of 'wave lift' is caused by the topographic barrier of a mountain so these types of cloud form thousands of feet in the air.

Movement
Due to being made up of mostly vertical wind flow (known as vertical oscillations), the clouds stay very still and can often form into stacks.

Airflow
Originating from a strong wind, airflow is always very rapid in a lenticular cloud, making it great fun for hang gliders but not so good for aircraft, which avoid them at all costs!

Shape
The shape is a distinctive saucer structure caused by the vertical wind flow in the centre of the motionless cloud.

Location
Lenticular clouds form almost exclusively near mountains and hills. When a strong wind is interrupted by a tall landmass, a wind-wave pattern is created.

The incredible singing fish

Find out how the midshipman fish sings to serenade a mate

Finding a mate in the sea is no easy task, but the male plainfin midshipman fish is one Casanova who has little trouble in attracting the females, thanks to its unique vocal talents. Capable of producing a deep humming sound for up to an hour at a time, the male midshipman fish, also known as the singing fish, will serenade females during the spring and summer months from its rocky underwater nest.

To do this, the midshipman fish will contract and relax sonic muscles surrounding their swim bladders. Reproductive female midshipman fish, which are capable of producing short bursts of grunting sounds themselves, will be able to locate the male's underwater nest where they lay their eggs for the male to fertilise.

There are two types of male midshipman fish, Type I, which can attract a mate using sound as explained and Type II, which are less vocal but have larger reproductive organs. Type II males typically wait near a Type I male's nest during mating season so that once a female has laid her eggs they can sneak in and fertilise as many of the eggs as possible for themselves.

"They will use their three pairs of prolegs in order to tunnel through soil and wood as they grow underground"

The life cycle of a stag beetle

It can take up to six years for the stag beetle to go from egg to adult – this is how it happens

1. Laying the eggs
Once a male and female stag beetle have mated, the female will burrow underground and prepare a nest next to decaying wood. Here she will lay 20 or more eggs.

2. Hatching larvae
It can take up to three weeks for the stag beetle's eggs to hatch. The emerging larvae are blind and will use their sharp jaws to free themselves from the egg.

3. Building strength
The hatched larvae's diet consists only of the decaying wood around them. They will use their three pairs of prolegs in order to tunnel through soil and wood as they grow underground.

4. Shedding skin
It can take between four and six years for the larvae to grow up to 80mm (3.1in) in size. To accommodate growth, they will shed their skin up to five times over the years.

5. Pupa stage
Eventually the larvae's will skin become brittle in preparation for the pupa stage, where it burrows deep into the soil and creates a cocoon. After six weeks, an adult stag beetle will emerge and remain underground until spring.

6. Adult stag beetle
Between May and August, the adult stag beetles will tunnel up to the surface where they will spend the last few months of their life in search of a mate. The male stag beetle will use its mandibles to attract a female and wrestle other males.

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Cardiff Castle

Why does Wales' most famous fortress look like something from a fairy tale?

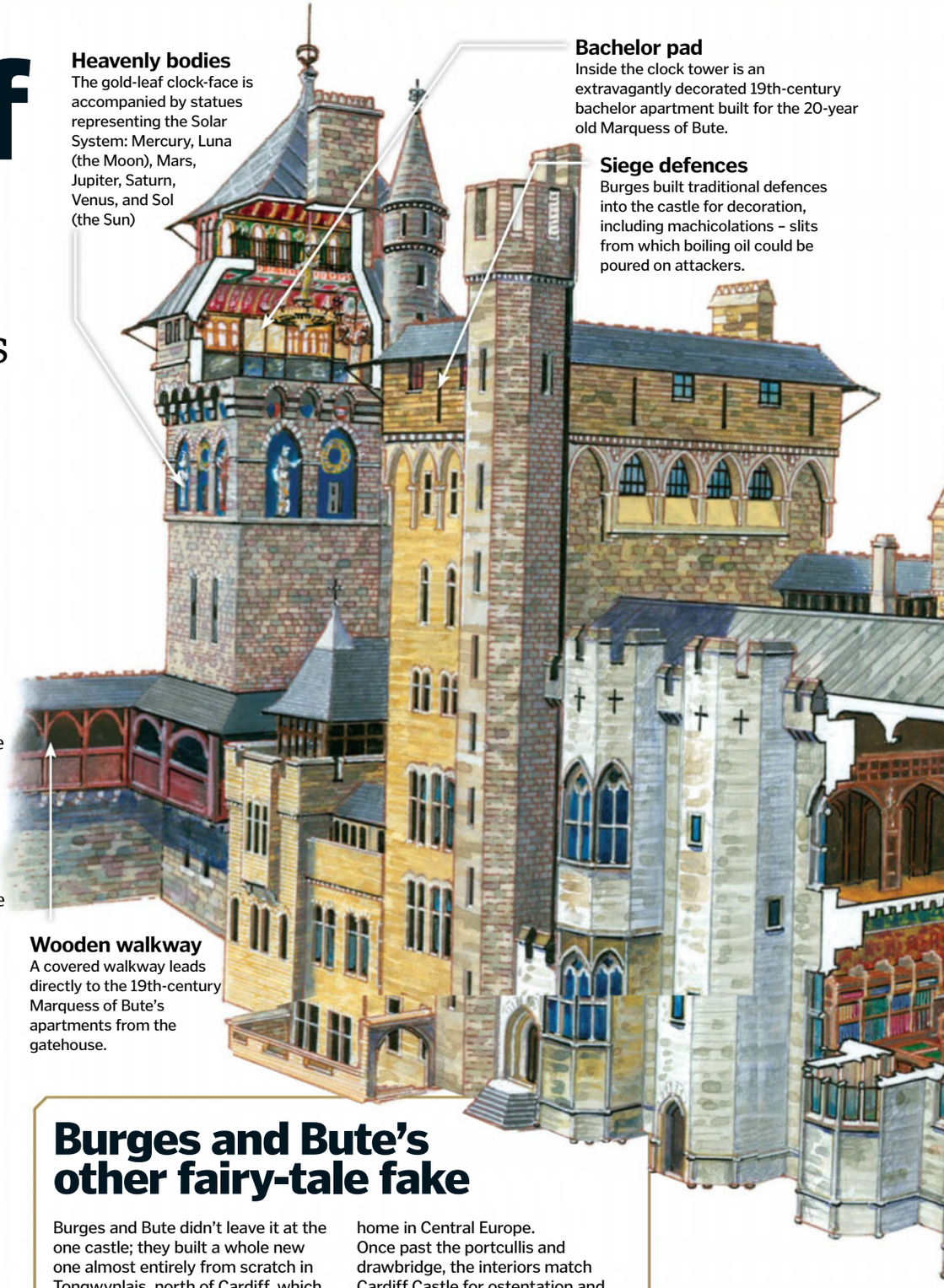
Adorned with elaborate sculptures, covered walkways and dominated by a striking clock tower, Cardiff Castle looks almost too good to be true.

Built sometime after 1081 over the ruins of a Roman fort by the Normans, who were then expanding from England into Wales, Cardiff Castle was extended in the following centuries, notably in the early-15th century, where the keep took shape, and in the 18th century, where it was embellished with a Georgian mansion.

In 1848, Cardiff Castle was inherited by John Patrick Crichton-Stuart, the third Marquess of Bute – then still not six months old – and its story soon took an unexpected swerve into the past. "My luxury is art", wrote Bute later. "I have considerable taste for art and archaeology, and happily the means to indulge them." Armed with his father's wealth and an eclectic taste in history, religion, art, literature and even the occult, the 18-year-old Bute struck up a friendship with eccentric architect and designer William Burges. The two began to rebuild and decorate Cardiff Castle to fit their dream of how a medieval castle should look.

Extensively remodelling the interior with cheeky carvings, stained glass, angelic statues and vaulted ceilings, Burges dwarfed the original building with Bute's new apartments in a 40-metre (130-foot) high clock tower decorated with the symbols of the Zodiac.

Sadly, Burges died in 1881 before his finest work yet – the breathtaking Arab Room, inspired by his travels to Sicily and Turkey – was complete and Bute paid tribute to his "soul-inspiring" friend in marble, carving both of their names where they can still be seen amid the fairy-tale fantasy of Cardiff Castle by stunned visitors today.



Heavenly bodies
The gold-leaf clock-face is accompanied by statues representing the Solar System: Mercury, Luna (the Moon), Mars, Jupiter, Saturn, Venus, and Sol (the Sun)

Bachelor pad
Inside the clock tower is an extravagantly decorated 19th-century bachelor apartment built for the 20-year old Marquess of Bute.

Siege defences
Burges built traditional defences into the castle for decoration, including machicolations – slits from which boiling oil could be poured on attackers.

Wooden walkway
A covered walkway leads directly to the 19th-century Marquess of Bute's apartments from the gatehouse.

Burges and Bute's other fairy-tale fake

Burges and Bute didn't leave it at the one castle; they built a whole new one almost entirely from scratch in Tongwynlais, north of Cardiff, which was to serve as the Marquess' summer home.

After clearing the weeds and debris away from the ruins of the 13th-century Castell Coch (Welsh for 'Red Castle') in 1871, construction began in 1875 and Burges 'rebuilt' the castle with three historically dubious coned towers and covered wooden walkways that would look more at home in Central Europe.

Once past the portcullis and drawbridge, the interiors match Cardiff Castle for ostentation and Castell Coch has been used by TV series such as *Merlin*, *Doctor Who*, *The Worst Witch* and *Da Vinci's Demons*. Rather unkindly, a 1954 *Welsh Office Official Handbook* describes Castell Coch as a "gigantic sham, a costly folly erected by an eccentric Victorian architect to satisfy the antiquarian yearnings of a wealthy nobleman." Ouch!

5 TOP FACTS
BURGES BUILDINGS

Worcester College, Oxford
1 Burges overhauled the 18th-century hall and chapel in 1864, adding carved animals and mosaics. Most of his work was removed in the 1960s.

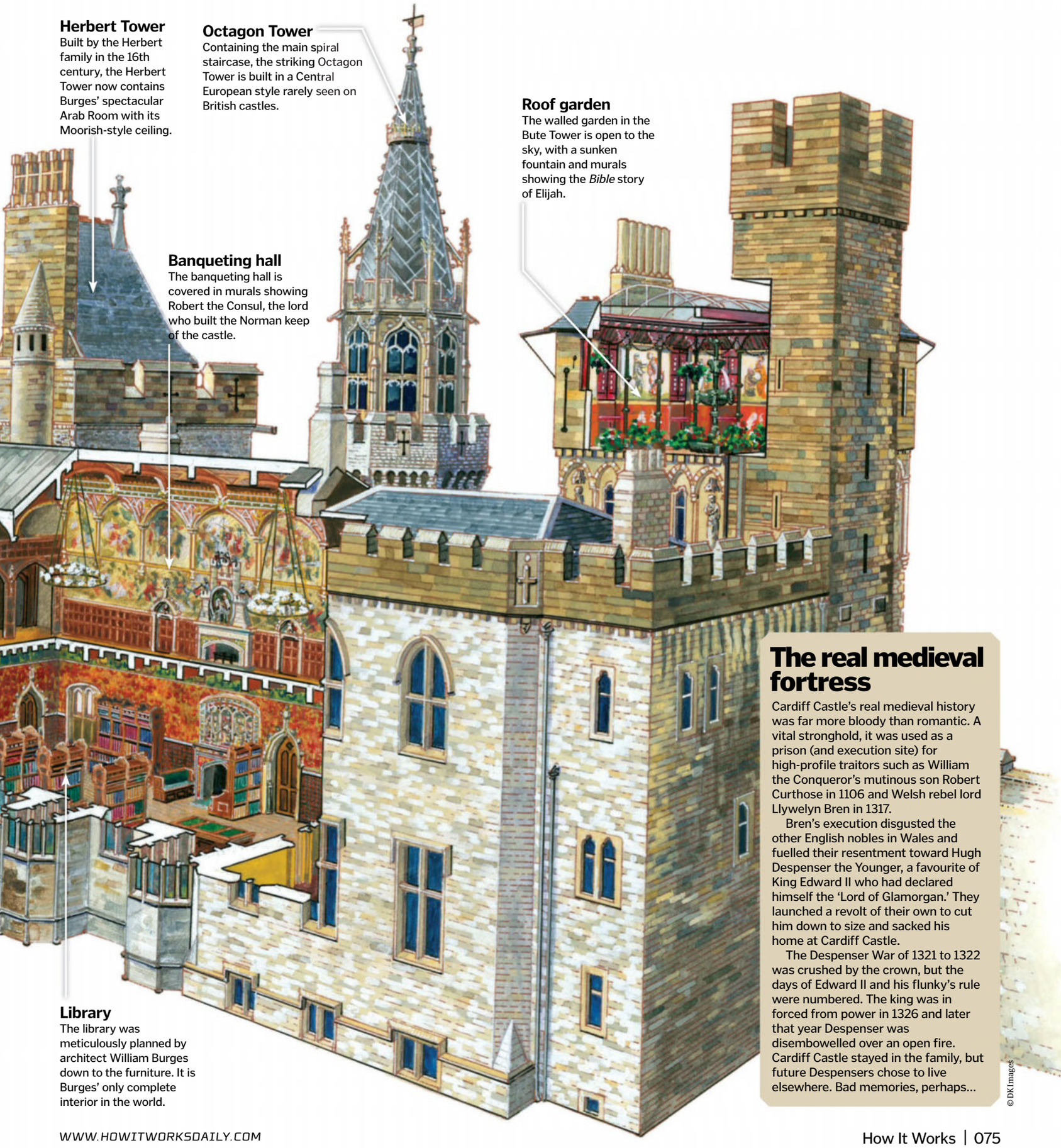
Knightshayes Court, Devon
2 He designed a new mansion for businessman and politician John Heathcoat-Amory, remarkable because it was the only conventional home he built.

Saint Fin Barre's Cathedral, Ireland
3 Burges' first major work, Saint Fin Barre's Cathedral is a graceful Gothic church that earned the architect a prize of £100.

Waltham Abbey, Essex
4 Restoring and remodelling the interior in 1876, Burges painted the ceiling with the signs of the Zodiac, something he later repeated at Cardiff Castle.

Mount Stuart House, Isle of Bute
5 The Marquess of Bute's family home was rebuilt by Burges in Gothic style. Mount Stuart was the first house to feature a heated swimming pool.

DID YOU KNOW? *One outside wall is decorated with 15 different animals – many were recarved because they weren't fierce enough*



Herbert Tower
Built by the Herbert family in the 16th century, the Herbert Tower now contains Burges' spectacular Arab Room with its Moorish-style ceiling.

Octagon Tower
Containing the main spiral staircase, the striking Octagon Tower is built in a Central European style rarely seen on British castles.

Roof garden
The walled garden in the Bute Tower is open to the sky, with a sunken fountain and murals showing the *Bible* story of Elijah.

Banqueting hall
The banqueting hall is covered in murals showing Robert the Consul, the lord who built the Norman keep of the castle.

Library
The library was meticulously planned by architect William Burges down to the furniture. It is Burges' only complete interior in the world.

The real medieval fortress

Cardiff Castle's real medieval history was far more bloody than romantic. A vital stronghold, it was used as a prison (and execution site) for high-profile traitors such as William the Conqueror's mutinous son Robert Curthose in 1106 and Welsh rebel lord Llywelyn Bren in 1317.

Bren's execution disgusted the other English nobles in Wales and fuelled their resentment toward Hugh Despenser the Younger, a favourite of King Edward II who had declared himself the 'Lord of Glamorgan.' They launched a revolt of their own to cut him down to size and sacked his home at Cardiff Castle.

The Despenser War of 1321 to 1322 was crushed by the crown, but the days of Edward II and his flunky's rule were numbered. The king was in forced from power in 1326 and later that year Despenser was disembowelled over an open fire. Cardiff Castle stayed in the family, but future Despensers chose to live elsewhere. Bad memories, perhaps...

"While it looked impressive on the page, de Vinci's ornithopter was never physically realised in his day"

How Leonardo da Vinci tried to fly

Discover the secrets behind the legendary inventor's incredible flying machine

Few individuals truly fit the much-overused sobriquet of 'man ahead of his time', but Leonardo da Vinci is one of the select band who undoubtedly fits into this category. His mind seemed to be of another time entirely, devising all sorts of inventions that would either pre-empt or form the basis for modern-day equivalents. The item that perhaps best of all encapsulates his capacity to work beyond the constraints of his time, however, is his visionary ornithopter flying machine.

Having spent much time watching and studying the flight of birds, he observed the different ways they flapped their wings while taking off and in mid-flight, and sought to mimic them in the construction of his ornithopter. Sharing similarities with the paragliders of today, it required a solo pilot to manually operate a system of pullies, levers and pedals with his hands and feet in order to simulate flight. A hand crank increased the production of energy and the wings were designed to flap – much like those of a bird.

However, while it looked impressive on the page, da Vinci's ornithopter was never physically realised in his day. While it may well have worked while in flight, the task of actually taking off proved to be an insurmountable obstacle, as there wasn't a known way of producing enough power to actually get it off the ground.

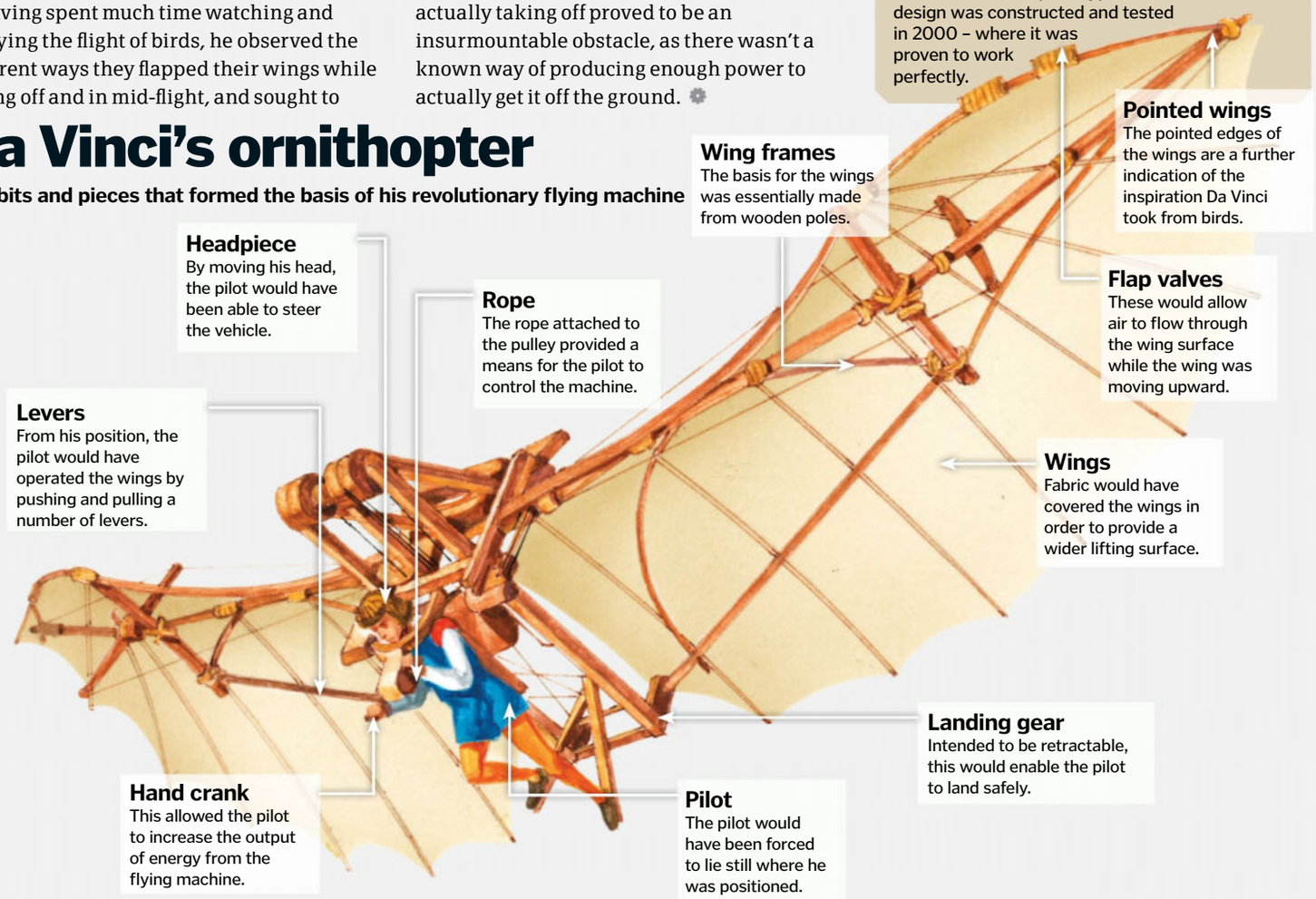
Da Vinci's other flying machines

Da Vinci didn't limit his pursuit of flight to just his ornithopter. Predating its invention by over 400 years, one of his designs reveals something akin to a modern-day helicopter. Also known as an aerial screw, its blades revolved like a corkscrew, compressing air in order to gain flight – a principle shared by its eventual successors. Although the theory was sound, modern-day scientists believe that it would have been too heavy to achieve flight, and as such remained strictly in the drawing book.

He is also credited with devising early designs for what would become what we know as the parachute. Despite its triangular shape and wooden frame causing many to doubt its effectiveness, it a prototype based on the same design was constructed and tested in 2000 – where it was proven to work perfectly.

Da Vinci's ornithopter

The bits and pieces that formed the basis of his revolutionary flying machine



Headpiece
By moving his head, the pilot would have been able to steer the vehicle.

Rope
The rope attached to the pulley provided a means for the pilot to control the machine.

Levers
From his position, the pilot would have operated the wings by pushing and pulling a number of levers.

Hand crank
This allowed the pilot to increase the output of energy from the flying machine.

Wing frames
The basis for the wings was essentially made from wooden poles.

Pointed wings
The pointed edges of the wings are a further indication of the inspiration Da Vinci took from birds.

Flap valves
These would allow air to flow through the wing surface while the wing was moving upward.

Wings
Fabric would have covered the wings in order to provide a wider lifting surface.

Landing gear
Intended to be retractable, this would enable the pilot to land safely.

Pilot
The pilot would have been forced to lie still where he was positioned.

1,357.6 km/h

FASTEST FREE FALL

Felix Baumgartner became the first human to freefall faster than the speed of sound when he hit 1,357.6km/h (843.6mph) during his Stratos jump on 14 October 2012.

DID YOU KNOW? *There are 20 quills laid out every day the US Supreme Court is in operation*

Medieval writing equipment

Why we used quills for over 1,300 years

Before the invention of the pen, most people used quills to write with. These were stripped bird feathers, usually from geese. Swan feathers were very sought after but geese, crow, owl and turkey feathers were more simpler to obtain.

Quills were easy to supply, comfortable to hold and tapered down to a point so the writer could create all the subtle curves and lines of fine handwriting.

The first record of their use was around the 6th century by European monks, replacing the reeds they had been using up until then.

Feathers were stripped, buried in hot sand to harden, hollowed out and then filled with ink. They were time-consuming to make and had to be refilled and reshaped regularly, but continued to be the main writing implement until the metal pen became popular in the mid-19th century.

How to make a quill

Travel back through time to the Middle Ages and write with feathers

Prime your feather

Scout around near a river or lake for a feather that has been dropped by a swan or goose. Ideally it should be around 15cm (6in) long and intact. Using a Stanley knife, very carefully shave off the fluffy feathers at the pointy end. You should be able to grip the quill without touching any feathers. Then place the feather in a bowl of water and leave it overnight to soak.

Toughen and shape

Heat sand in the oven at 175°C (350°F) and bury the feather, using oven gloves to avoid burns. Wait until the sand has cooled and remove the hardened feather. From about 2.5cm (1in) above the tip, slice down at an angle of around 45 degrees to the tip of the feather. Make a small, flat cut on the opposite side of the tip. There should now be two spikes on the tip that you need to pinch together.

Finishing off

Shave the pinched end so it is nice and smooth and you should have a feather tapering nicely to a point. Dip your quill in the ink where it should soak up the writing fluid. There should be enough to write a fair few lines, depending on how tightly you've pinched it together. The tighter you've pinched it, the more ink it should retain. Take it out and begin writing like a medieval scribe!

Breaking the sound barrier

What was the first thing to go faster than sound?

The first time that magical speed of 1,225 kilometres (761 miles) per hour was breached dates back to the Ancient Egyptians. They are one of the first civilisations recorded as using a whip, which has been creating sonic booms for over 4,000 years.

Lifting a whip and bringing it down sharply causes a ripple to move down the length of the whip as it rises up then snaps back down. As the wave moves along, it gets faster as the whip gets thinner. This continues until it reaches the tip and the thinnest part of the whip. If you have done it right, by this point the wave is moving so fast that the tip breaks the sound barrier as it flicks up, creating that characteristic crack.

Incidentally, the first human to travel faster than sound was US Air Force Captain Chuck Yeager as he flew an X-1 plane at Mach 1 – the speed of sound – in 1947.

"The projector is a low-cost teaching aid, as the transparencies can be used again and again"

How do overhead projectors work?

The science behind the classroom classic

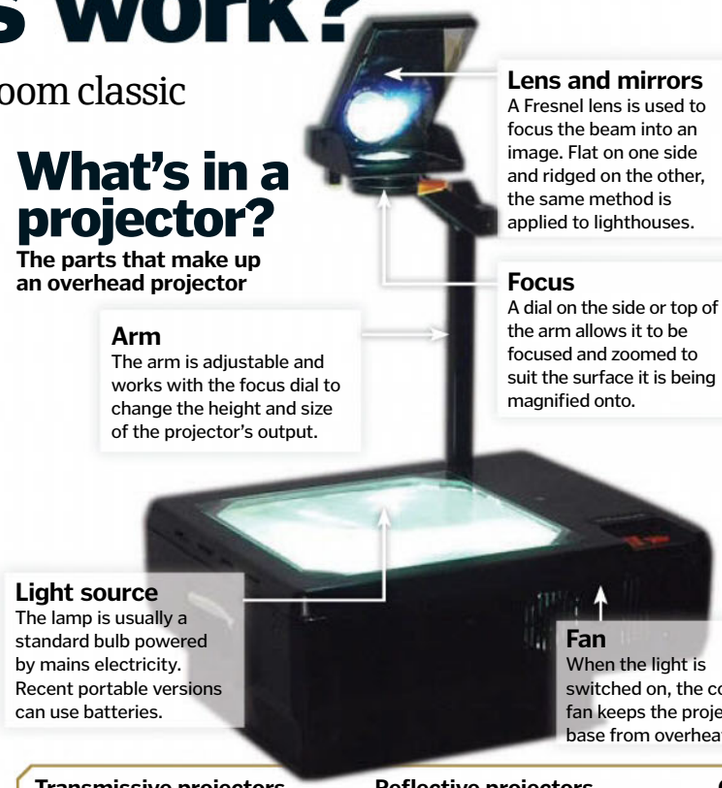
Anyone who went to school in the 1980s and 1990s will remember the overhead projector. Its roots can be traced to a device known as a magic lantern. This was introduced in the 17th century and used candles, lamps or the Sun itself as its light source and an array of mirrors to display painted images.

An overhead projector works by placing a transparency – an A4 sheet of plastic – on top of main projector base. This has a glass top with a lamp underneath, allowing the light to shine through the sheet, reflect off the mirror, out through the lens and onto the surface that it's pointed at.

The projector is a low-cost teaching aid, as the transparencies can be used again and again. Written material can be preprinted onto the plastic sheets and notes can be added in nonpermanent marker, which saves teachers time and resources. However, in recent years the use of the projector has declined due to the rise of computers and LCD projection, as well as presentation programs such as Keynote or Microsoft PowerPoint.

What's in a projector?

The parts that make up an overhead projector



Lens and mirrors
A Fresnel lens is used to focus the beam into an image. Flat on one side and ridged on the other, the same method is applied to lighthouses.

Focus
A dial on the side or top of the arm allows it to be focused and zoomed to suit the surface it is being magnified onto.

Arm
The arm is adjustable and works with the focus dial to change the height and size of the projector's output.

Light source
The lamp is usually a standard bulb powered by mains electricity. Recent portable versions can use batteries.

Fan
When the light is switched on, the cooling fan keeps the projector base from overheating.

Transmissive projectors
Transmissive projectors use an adjustable head and a Fresnel lens to focus the image. These hulks are fast becoming obsolete.

Reflective projectors
The light source is in the head of the projector rather than the base, which shines the light down onto reflective mirrors.

Opaque projectors
Using the same system as the reflective projector, these machines can also display opaque paper and 3D objects.

The first vacuum cleaner

How this horse-drawn vacuum cleaned Victorian houses

British engineer Hubert Cecil Booth patented the motorised vacuum cleaner in 1901. Far from the slender pieces of equipment we have nowadays, this vacuum cleaner was so cumbersome it had to be drawn by a horse and cart. Because most Victorian houses didn't have electricity, Booth's machine had to get its power from coal or oil. It would park outside a house and a 244-metre (800-foot) long hose would snake in through the windows and the oil-powered engine would burst into life. It sucked the dirt into a filter, ridding homes of years and years of accumulated dust. Far too big for everyday use, Booth successfully marketed it as a hired service and was even asked to clean the ceremonial carpet for King Edward VII's coronation!

5 TOP FACTS
ZULU WEAPONS

1 Axe
A semi-circular iron blade attached to a wooden handle, the Zulu axe was used by the most esteemed leaders and had to be held in both hands.

2 Club
A 0.6m (2ft) hardwood club with a knob on the end, the iwisa – also known as the knobkierie – can either be thrown or used similarly to a mace.

3 Spear
A long, thin throwing javelin, the ipapa spear was once the traditional weapon of the Zulu, but it was replaced with the shorter iklwa by Shaka.

4 Poison
Zulu warrior would poison their spear-tips with an extract from the bark of the combretum caffrum tree. Parts of the tree are also used in traditional medicine.

5 Rifle
The Zulus also captured many single-shot Martini-Henry rifles at the start of the Anglo-Zulu War. These were the standard firearm of the British Army.

DID YOU KNOW? *The Zulu are still the largest ethnic group in South Africa and Zulu is a widely spoken language in the country*

Secrets of the Zulu warriors

How did the Zulus become South Africa's most feared fighting force?

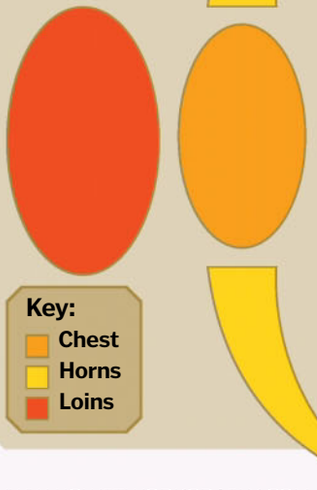
From 1816 to 1879 the Zulu Kingdom became one of the most powerful tribal societies in what is now South Africa. Only the arrival of the British Empire finally ended their expansion across the KwaZulu-Natal region in the bloody Anglo-Zulu War of 1879, after which the Zulu Kingdom became subject to the authority of Queen Victoria.

Born around 1787, Shaka Zulu, the illegitimate son of chieftain Senzangakhona, had a lot to prove, and he did so the hard way. Taking control after his father's death, Shaka curbed the power of the witch doctors and transformed the army with reforms. Among those was a policy of absorbing defeated tribes into his kingdom and promoting men based on ability rather than family ties.

Zulu warriors also gained new weapons, including the short, stabbing iklwa spear (the name gruesomely said to be the sound made when pulled from a corpse), and revised tactics. Zulu warriors were trained harshly too, forced to throw away their sandals so they could run faster – those who complained were simply killed – they reportedly jogged up to 80 kilometres (50 miles) in a day, with children as young as six running after them with food and other supplies.

By Shaka's death in 1828, the Zulu Kingdom had expanded to cover an incredible 29,800 square kilometres (11,500 square miles) and ruled an estimated 250,000 people.

The Zulu's killer formation



The 'Buffalo horn' or 'bull-horn' formation was the core battle strategy of a Zulu army. It had originally been developed for hunting, but Shaka began to use it in battle, with devastating success.

The bulk of the force would be in the middle as the 'chest' of the buffalo, made up of battle-hardened warriors. They would charge into the enemy and keep them well and truly occupied while two smaller forces of 'horns' would circle around either side to completely surround their foe. The horns were often comprised of younger and faster warriors.

A fourth force, the 'loins', would be held in reserve ready to provide reinforcements if the enemy looked like they might break out of the Zulu's deadly trap.

The anatomy of a fearsome warrior

What items the Zulu took into battle and how they used them

Headdress
Each regiment wore a matching headdress, usually consisting of a leopard-skin band with a feather plume.

Necklace
The more important the warrior, the more elaborate the necklace – kings like Shaka Zulu wore lion teeth.

Shield
Shaka introduced the longer oxhide shield so that the warrior could crouch beneath it or knock his enemy off balance.

Cow tail
Oxtails were worn on the legs and upper arms to make the warrior's muscles look bigger from a distance.

Iklwa
The short-handled stabbing spear would be jabbed under-arm up into the enemy's ribs.

Coat of arms
Each regiment used a different pattern of oxhide so they could be instantly recognised by its colours.

Bare feet
Fighting without sandals allowed the Zulus to move quickly and quietly through the tall grass.

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

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How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He has been writing about science and technology since before the web was invented. His sci-fi novel *A Jar of Wasps* is out now.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Alexandra Cheung

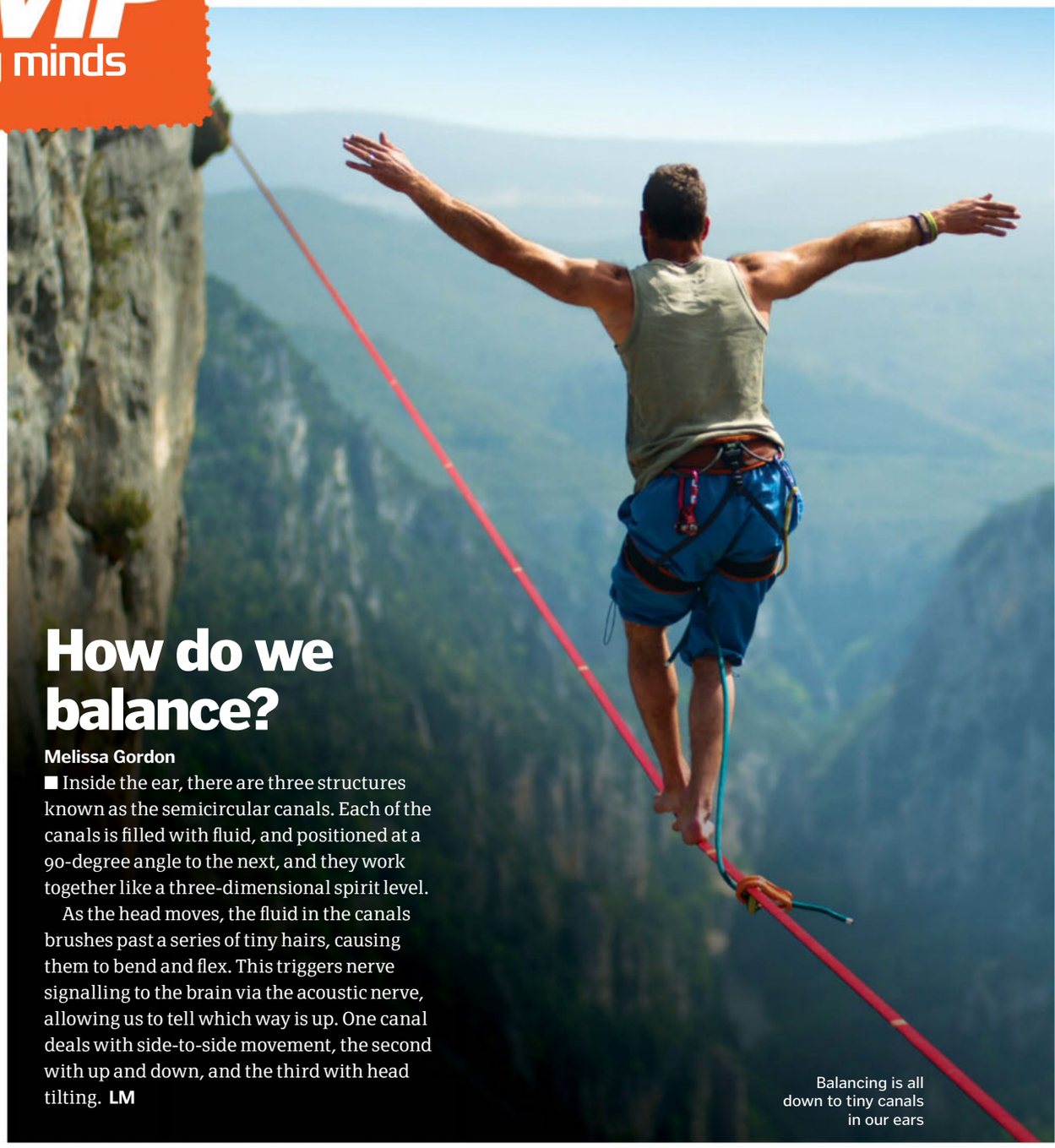
Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from the University of Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!



How do we balance?

Melissa Gordon

■ Inside the ear, there are three structures known as the semicircular canals. Each of the canals is filled with fluid, and positioned at a 90-degree angle to the next, and they work together like a three-dimensional spirit level.

As the head moves, the fluid in the canals brushes past a series of tiny hairs, causing them to bend and flex. This triggers nerve signalling to the brain via the acoustic nerve, allowing us to tell which way is up. One canal deals with side-to-side movement, the second with up and down, and the third with head tilting. **LM**

Balancing is all down to tiny canals in our ears

Why are flowers different colours?

Poppy Johnson

■ Flowers use colour to attract the insects and birds that pollinate them. Different flowers have evolved to be pollinated by different animals and their colours have evolved to target the differences in their eyesight. For example, bees don't see red well, so flowers pollinated by bees tend to be yellow, blue or purple. On the other hand, flowers that attract hummingbirds are usually red. At night, colour vision of any kind is very difficult and flowers tend to be white or very pale in order to stand out against dark foliage, for the benefit of moths. **LV**

Do any animals speak different languages?

Hywel Price

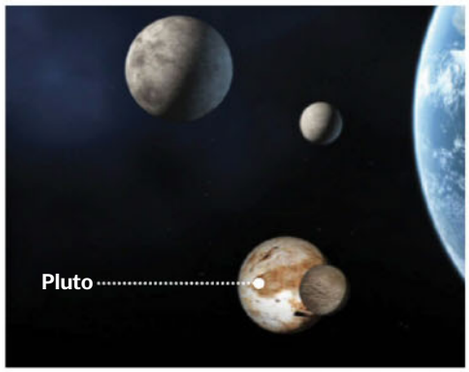
■ Humans have different languages because we learn as infants by listening to adults and, over thousands of years, different countries have gradually diverged to use different sounds for things. Most animals have much simpler languages that are hard-wired at birth. In 1989, researchers tried swapping newborn Japanese and rhesus macaques, so that each was fostered by parents of the other species. Initially, these infants stubbornly stuck to the particular grunts and coos of their own species, despite never having heard them from their adopted families. But whales, bats and many songbirds do show regional variations. There are nine known dialects of song for blue whales, for instance. **LV**

Rhesus macaques don't have the same language adaptability as humans

FASCINATING FACTS

Swimming across the English Channel takes a lot of energy

Swimming across the English Channel can take anywhere from seven to 27 hours, burning a total of around 9,500kcal for the average swim time of 13 hours - that's over 31 cheeseburgers.



Why is Pluto no longer a planet?

Sam Sanderson

■ Pluto ceased to be a planet when the International Astronomical Union (IAU) formally defined planethood at a conference in 2006. Specifically, a planet must be in orbit around the Sun, be massive enough to be spheroid due to its own gravitational force, and have cleared the neighbourhood around its orbit, ie being the dominant body in its orbital zone). Pluto doesn't meet that last condition, because its mass is just 0.07 times greater than other objects in its orbit. At the same time, the IAU created the dwarf-planet category for Pluto and other trans-Neptunian objects of similar size. **SF**

Why do we have eyelashes and eyebrows?

Warren Churchfield

■ The reason we have eyelashes and eyebrows is ultimately for protection. Our eyes are valuable and delicate organs and even a slight intrusion can lead to temporary or permanent damage. Eyelashes prevent dust from getting in our eyes. They don't stop all dust, of course, but help keep out the majority of particles that come into close contact with our eyes. Eyebrows work in a similar way in order to help keep moisture out of our eyes when we sweat or if we are exposed to water. They come in all shapes and sizes, but are generally arch-shaped to divert this moisture around the eyes. **SB**

Why does caffeine make you more awake?

Philip Delaney

■ Caffeine binds to adenosine receptors in the brain, blocking out the molecules that usually slow down neural activity. Throughout the day, your brain's neurones produce small quantities of adenosine. As adenosine molecules bind to neural receptors, they slow down activity in the brain and cause growing feelings of drowsiness. However, caffeine binds to these same receptors, stopping adenosine from putting on the brakes and thus allowing neural activity to go unchecked. What's more, this also causes the body to produce more adrenaline, giving you an extra burst of energy and increasing your heart rate. **AC**

How much is a pound worth? Find out on page 82

BRAIN DUMP

Why do huge things like whales only eat tiny things like krill?

Robyn Wilkins

Actually, their diet of krill is precisely what allowed baleen whales to get so big in the first place. Antarctic krill are possibly the most abundant single species on the planet – there are about 500 million tonnes of them altogether. What's more, they swim in large, dense swarms, which makes it easy for a blue whale to hoover up the 1.5 million calories it needs every day. The 'biggest eat the smallest' isn't a hard and fast rule though. A large part of the diet of sperm whales comes from the giant squid, and the even larger colossal squid. **LV**

Fortunately for whales, most of their food doesn't fight back as hard as the giant squid

How do you work out the value of the British pound?

Eric Bowerbank

Also known as the pound sterling, it got this name because it was originally the value of one Troy pound of sterling silver. Adopted as the Royal Chartered Bank of England's currency in 1694, around a century later the bank was forced to stop paying out gold for its notes and therefore issued banknotes of one and two pounds instead of coinage in an attempt to get its finances back on track. In 1983, the one-pound banknote was replaced by a one-pound coin. However, the British one-pound coin technically began with the gold sovereign, first issued for Henry VII in 1489. **SB**

What would happen if my microwave had a hole in it? Would radiation leak into the kitchen?

Felix Fawcett

For radiation to leak out of your microwave, the hole in the oven would have to measure 12 centimetres (4.7 inches) or more across. Like visible light, microwaves are a form of electromagnetic radiation and can pass through paper, plastic or glass, but reflect off the oven's metal walls. A household microwave produces radiation with a frequency of 2,450MHz, optimised to excite water molecules and thus heat up your food. These waves have a wavelength of 12 centimetres (4.7 inches), meaning they cannot pass through gaps any smaller than that. Microwave doors are typically made of glass lined with a metal wire mesh, which allows you to check up on your dinner without letting radiation out. If there was a sufficiently large hole, microwaves could escape. However, the waves produced by a microwave oven are non-ionising, carry relatively little energy and would dissipate quickly, making it unlikely they would cause significant harm. **AC**

FASCINATING FACTS

Why you rarely see baby pigeons

Pigeon chicks stay in their nest until they are four to six weeks old. You've probably seen juvenile pigeons, though – their plumage is virtually identical to the adults so they are difficult to tell apart.

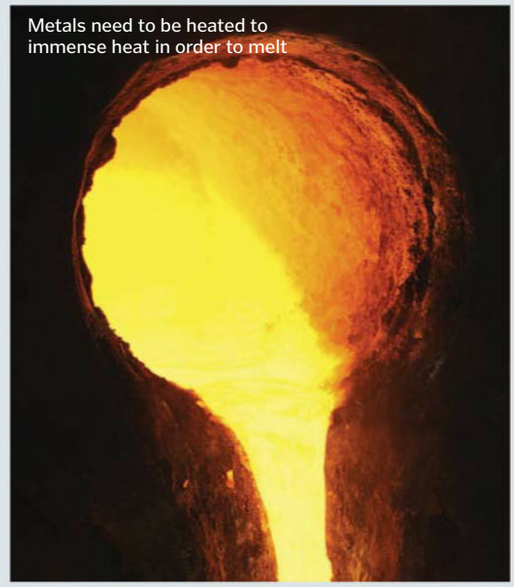
The heaviest one-arm curl in history

A man named Jon Paul Palmer managed to lift – or curl – 47.6kg (105lb) with one arm while doing a dumbbell curl in 2011.

Why do different materials have different boiling and melting points?

Giuseppe Diamante

The boiling and melting points of a substance depend on the strength of the bonds holding its molecules or ions together. In ice, for example, relatively weak bonds connect H_2O molecules to their neighbours. As you increase the temperature to zero degrees Celsius (32 degrees Fahrenheit), the molecules vibrate faster and faster until these bonds break, leaving the molecules bound very loosely as liquid water. The bonds holding together ions inside metals on the other hand are very strong. It therefore takes a lot of energy and very high temperature to cause metals to melt. **AC**



Metals need to be heated to immense heat in order to melt

How do remote controls work and when were they invented?

Xi Bo

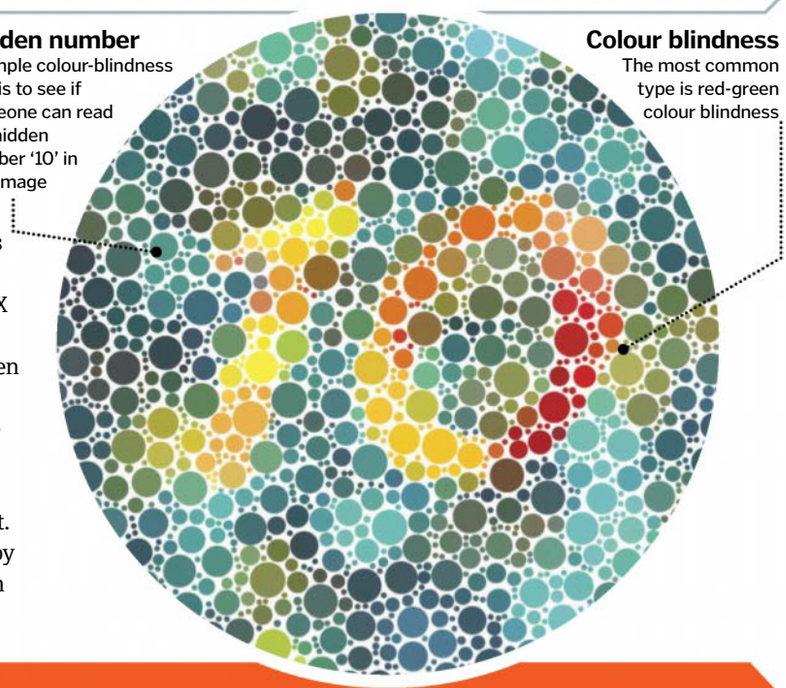
The first television remote control – called "Lazy Bones" – was invented by the Zenith Radio Corporation in 1950 and connected to the TV by a wire. A wireless remote control came on the market five years later, but it didn't work very well. It worked by shining light onto a photoelectric cell on the TV, but had to be carefully aimed, and light from other sources could also cause your channels to change. If you've ever heard a remote control called a 'clicker', that originated with a remote made in 1956 that made a clicking sound when the buttons were pressed. They emitted ultrasonic sounds received by a microphone on the TV, but this system wasn't ideal either. So in the 1970s, more complex remotes that used infrared technology were developed. The latest remotes use Bluetooth or radio waves, eliminating the need for aiming the remote directly at the television. **SF**

What makes people colour-blind?

Brian Millbank

Colour blindness is most often inherited, but it can also be caused by damage to the eyes. The human retina has three different colour-sensitive cone cells, responding to light in the red, green and blue parts of the spectrum, but in some people, these cells do not function properly, or are missing altogether.

There are various different kinds of colour blindness, categorised according to the particular pattern of colours that can and cannot be seen, but the most common type is red-green colour blindness. The gene responsible is carried on the X chromosome, thereby linking the condition directly to gender. Women (XX) have two copies of the chromosome, while men (XY) have just one. If a woman has one faulty allele, she can compensate using the good copy, while a man can not. That means the condition is thereby much more common in males than in females. **LM**



Can you sneeze in your sleep? Find out on page 84

BRAIN DUMP

How does the human body work during REM sleep? Can you sneeze while asleep?

Taryn L

As the name suggests, our eyes usually move rapidly in various directions during rapid eye movement (REM) sleep. Furthermore, our muscles turn off and the body becomes immobile and relaxed. This process provides the brain and body with energy that will improve performance the following day. Levels of the hormone cortisol decrease initially and then increase throughout the sleep to further aid next-day alertness. While our bodies are inactive, our brains are very much active, working to create the dreams we have. However, it is not possible to sneeze while asleep. When dust, allergies or illness stimulate nerve cells in the nose, these nerve cells send signals to the brain, which helps us get rid of the irritant by making us sneeze. During REM sleep, certain neurotransmitters stop working and motor neurons are not stimulated, so signals aren't sent to the brain. If external stimulants do trigger the need to sneeze, we wake up first. **SB**

Are mathematical symbols for adding, subtracting, multiplying and dividing the same all over the world?

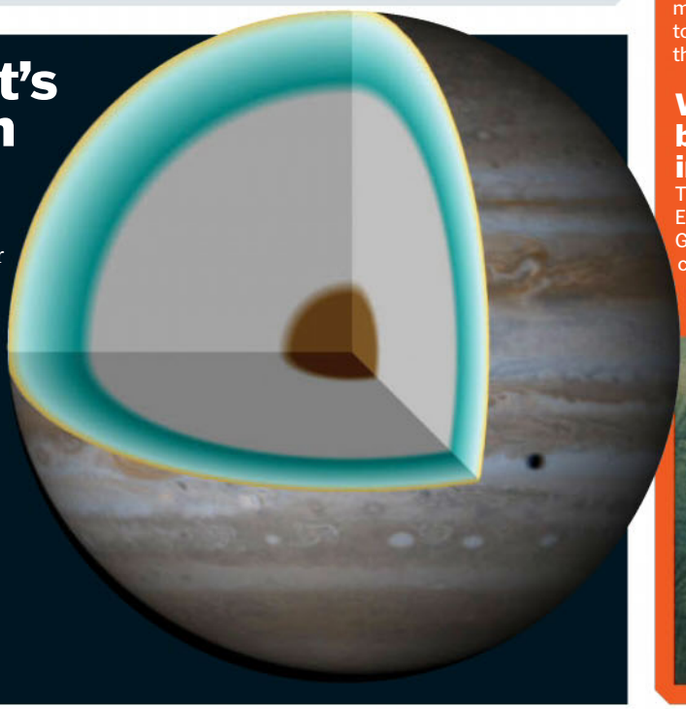
Dora Marquez

It's been said that mathematics is the universal language, but the reality is that the concept of math is universal (math isn't really a language). It would be impossible, for example, to work a math problem that was written in Chinese numerals if you only know the Hindu-Arabic numeral system – the most commonly used system in the world. But you'd still recognise the symbols that express a constant or a formula, such as a plus sign to mean 'add these numbers together', if nothing else. One difference might be if the language used is Arabic. As it is read from right to left instead of left to right, some of the symbols are reversed so that it's easier to read. **SF**

After the Sun, what's the hottest thing in the Solar System?

Jessica Anderton

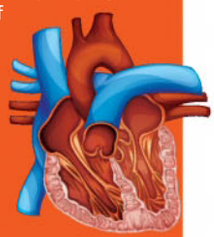
Outside of the Sun, the hottest place in the Solar System is Jupiter's core, which can reach an estimated 35,000 degrees Celsius (63,032 degrees Fahrenheit). The hottest surface in the Solar System is on the planet Venus. Its surface has an average temperature of 462 degrees Celsius (864 degrees Fahrenheit). Humans have produced hotter temperatures than the Sun several times, though. The European Organization for Nuclear Research (CERN)'s Large Hadron Collider, for example, broke reached 4 trillion degrees Celsius (7.2 trillion degrees Fahrenheit) during experiments using heavy ions. That's 250,000 times hotter than the centre of the Sun. **SF**



FASCINATING FACTS

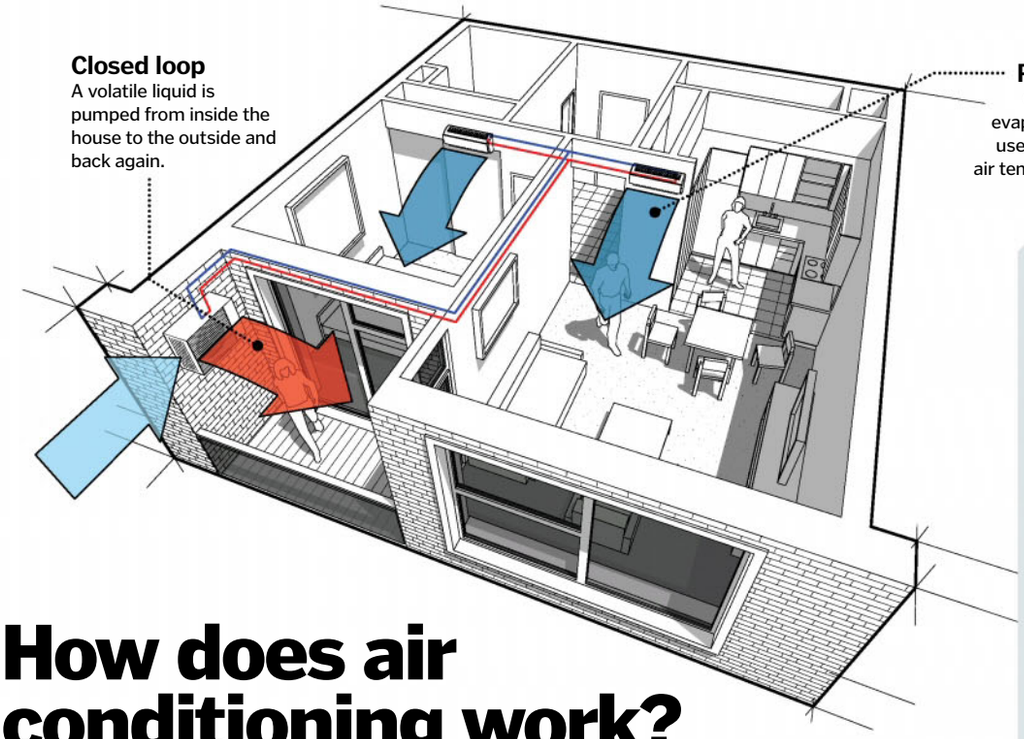
One-minute round trip

The human heart beats an average of 75 times a minute, pumping 70ml (2.4 fl oz) of blood each time. An adult has around 5l (1.3gal) of blood, so it only takes around a minute for blood to travel around the whole body.



Who ruled over the biggest-ever empire in the world?

The biggest empire was the British Empire in 1922, ruled by King George V. Its maximum land area covered more than 33mn km² (13mn mi²), almost a quarter of the world's entire land area.



How does air conditioning work?

Oliver

An air conditioner is a closed loop that pumps a volatile liquid from the inside of the house to the outside and back again. As the liquid passes through the indoors leg of the circuit, the heat from the room makes the liquid evaporate. This absorbs heat energy as the molecules change from liquid to gas phase. The coolant vapour is then pressurised by a compressor to make it even hotter and pumped through the outdoors section of the loop. As the gas is hotter than the outside temperature, it loses heat to the environment and at this higher pressure, it condenses back into a liquid. It can now be pumped back to the inside, through an expansion valve, which reduces the pressure. This boils off some of the liquid, which cools it back down to the point where it is colder than the room and the cycle repeats. **LV**

Why does our hair turn grey?

Olga Turnochuk

Pigment in the hair is produced by cells known as melanocytes and comes in two varieties, brown eumelanin and red pheomelanin. This is produced in the scalp and is taken up by the hair as it grows, but our melanocytes become less efficient with age.

Gradually, pigment production starts to slow down and the amount of colour available to each strand of hair decreases. The mixture of pigmented and non-pigmented hairs makes the overall colour appear grey. Eventually, the melanocytes die and pigment production halts altogether, allowing the natural semitranslucent or white colour of the hair to show through. **RS**

Why do people like different foods?

Ella Chamberlain

The tip and the sides of the tongue have lots of fungiform (mushroom-shaped) papillae, responsible for sensing the five different tastes; sweet, sour, bitter, salty and umami. Different people have different numbers of these bumps, allowing them to be broadly separated in to three groups: non-tasters, medium tasters and supertasters.

Supertasters can have as many as ten times more fungiform papillae than non-tasters, and as a result, are much more sensitive to flavour. They report that sweet foods taste sweeter, fatty foods taste creamier, and they often dislike the taste of bitter foods, like broccoli, cabbage and brussel sprouts. **LM**

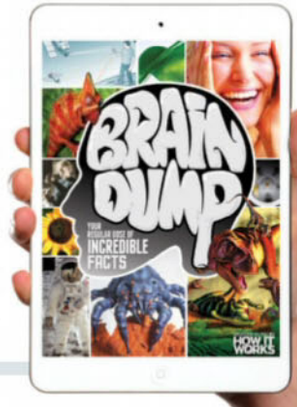
Who invented the first-ever digital camera?

John Chang

Astonishingly, the first-ever digital camera was invented way back in 1975 by electrical engineer Steven Sasson who worked at Eastman Kodak, a US technology company. Here he not only invented the camera, but also built it using a charge-coupled device image sensor and various other parts he collated from the lab and elsewhere. The camera weighed 3.6 kilograms (eight pounds) and recorded 0.01-megapixel black-and-white photos to a cassette tape, from which data was read and the images displayed on a television. It took almost half a minute to process the first photo from it. **SB**

New Brain Dump is here!

Don't miss issue 16 of **Brain Dump**, the digital sister magazine to **How It Works**, which landed on the digital newsstand on 1 September. You'll find the answers to fascinating questions, including: how are pearls formed? Why is chocolate bad for dogs? And why is the sea salty? There's also a look at the engineering behind the huge Chinook CH-74. As always, this issue is packed with stunning imagery as well as need-to-know facts about the world around us. Download **Brain Dump** on the first of every month from iTunes or Google Play. If you have a niggling question that you want answered, then get in touch via **www.facebook.com/BraindumpMag** or Twitter **@BrainDumpMag**.



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Mobile gadgets

We take a look at the most entertaining and essential add-ons for your smartphones and tablets

Phones are no longer just for calls and a tablet is more likely to be plugged in than gulped down, so now there are a wealth of extras to enhance your gadgets. Delving into that fast-evolving world, we take a look at the coolest additions for your smart devices.

The Roku stick can link with Netflix or NowTV, providing a near-unlimited TV choice.

The monopod extends up to 1m (3.3ft) and comes with an adjustable mount.

Checklist

- ✔ Selfie stick
- ✔ Charging case
- ✔ Case stand
- ✔ Juice pack
- ✔ Sync dock
- ✔ Microphone
- ✔ Roku remote

1 Extensive selfies

Bluetooth Selfie Stick
£19.99/$N/A
www.everythingtablet.co.uk
The selfie stick has an extension arm for capturing self-portraits from a high-angle. This helps to include more than one person in the shot, as well as photographing more of the scenery. It's hooked up to your mobile via Bluetooth and compatible with all Android and iPhone devices.
Verdict: ●●●●○

2 Link up

Roku Streaming Stick
£49.99/$49.99
www.roku.com
You can turn your mobile into a remote control for the Roku player. The tiny stick plugs into your HDTV and lets you stream over 750 channels, freeing your laptop by transforming your television into a smart TV. It's small but mighty and the mobile app means you'll never have to hunt for the remote again.
Verdict: ●●●●●

3 Stand it up

360° tablet case
£19.99/$19.99
www.everythingtablet.co.uk
If you're watching a film on your Nexus 7 or just feeling a bit lazy, this sophisticated case flips into a stand. The stand rotates, so it can hold your tablet in either landscape or portrait position, with a groove running along the base for extra stability. It's only 200g (7oz) so it's lightweight as well.
Verdict: ●●●●○

4 Sing it loud

iRig Voice microphone
£29.99/$39
www.ikmultimedia.com
A decade ago, the only way you could pretend to be a pop star was to sing into your hairbrush, but now you've got an all-singing, all-dancing (not really) microphone that plugs into your mobile. Synced to the EZ Voice app, you can download songs and sing along with good audio playback.
Verdict: ●●●○○

5 On the charge

Charge + Sync Dock
£27.99/$29.99
www.belkin.com
Belkin has released a product that promotes itself as a charging and sync dock, but essentially is just a lightning cable with a stand, which doesn't even hold your iPhone 5 particularly well. It looks nice and it works, but you could easily just buy a lightning cable for a lot less for the same effect.
Verdict: ●●○○○

6 Just in case

Mophie Juice Pack
£109.95/$119.95
www.mophie.com
This is a slick and stylish charging case that is able to more than double the battery life of your iPhone 5 or 5S. It can increase your available talk time by ten hours and give you an incredible 50 hours of audio playback. It is strong and shock-proof so works well as a standalone case.
Verdict: ●●●●○

7 Mobile power

iPhone Power Case
£32.99/$49.99
www.everythingtablet.co.uk
We've all run out of juice at the worst time possible, which is why this iPhone charging case is an absolute must-have. It takes five hours to charge and can triple the battery life of your iPhone 5, 5S or 5C. It looks stylish, works very well and most importantly, it could save you from getting stranded without power!
Verdict: ●●●●○

EXTRAS

All you need to become a mobile wiz

BOOK

Expert Android: Revised Edition

Price: £9.99
Get it from: imagineshop.co.uk
There is a ridiculous amount of things you can do on your Android phone you probably don't know about, which is where this handy bookazine comes in.

APP

Angry Birds

Price: Free
Get it from: iTunes / Google Play
In one of the most popular apps ever, you catapult a variety of birds into structures hiding pigs, trying to destroy the buildings and the pigs for points. Mad? Maybe. Fun? Definitely.

WEBSITE

icreatemagazine.com

Hints, tips and tricks from the team behind **iCreate** magazine. Check out tutorials, reviews and news for all Apple owners. It's engaging, informative and step-by-step guides are really helpful if you want to get the most out of your iOS device.

GROUP TEST

Putting products through their paces

Beginner's telescopes

Get stargazing with the latest ready-to-go telescopes

ON THE HORIZON

Cool tech for exploring the world from home

The Pocket Drone

If the armies of the world can have them, why can't we? This awesome remote-controlled drone can fly around at your command with a camera attached to the front for exploring.

SkyBell

If you hate getting up to answer the door, only to find out it's someone doing a street survey, then you can screen them on your smartphone with this cool doorbell/camera.

DEV50 digital binoculars

If you enjoy a bit of bird watching then you will love these digital binoculars that give you 12x optical zoom as well as the ability to record your findings.

1 Sky-Watcher 130

Price: £179/$N/A
Get it from: www.delonghi.com

The most hi-tech and advanced of the three, the Sky-Watcher 130 is a fairly hefty piece of kit. Very well made, solid and gorgeous to look at, this telescope makes you feel like a serious stargazer. It does take a while to put together, over half an hour, but when you finally get it together, it is capable of delivering an impressive 260x magnification. It also comes with a Barlow lens that improves its range.

The main body is by far the biggest of the three and weighs 4.21 kilograms (9.28 pounds), requiring a counterweight to keep it balanced, so this is definitely not recommended for children. Its huge mirrors gather plenty of light, enabling you to see a lot more detailed pictures.

The finderscope is also really useful, allowing you to line up a target with a red dot on the end of the finder so you can locate it more easily when looking through the telescope. This is a great advanced model and, for the price, offers excellent value.

Verdict: ✪✪✪✪✪

Near and far
The two eyepieces provide 75x magnification and 24x magnification, which is good considering the telescope's focal length is very short.

2 Visionary Starla 80

Price: £199.99/$N/A
Get it from: www.opticalhardware.co.uk

Although it looks like a serious and scary bit of kit, the Starla is very easy to set up and get started with. In fact, it took longer to unpack than to assemble! Everything clips and twists smoothly into place, so you can tell the build quality is high.

The telescope itself has a focal length of 900mm and comes with two eyepieces, a Plössl 10mm and Plössl 25mm, both of which provide clear views of the sky. It's pretty manoeuvrable, although it would be better if there were a single rod to move the telescope around. The main rod moves it only up and down while a catch on the side lets you move it side to side.

Aside from the tiny manoeuvrability issue, this is a really good beginner machine. It looks the part, is easy to set up, comes with a couple of eyepieces and there is scope (pun intended) to add more as your passion and ambition grow.

Verdict: ✪✪✪✪✪

3 Visionary First View

Price: £49.99/$N/A
Get it from: www.opticalhardware.co.uk

If you're at the start of your stargazing days, this compact, basic telescope is a good place to begin. It comes almost fully formed, so all you have to do is pop on the eyepiece and finder scope, both of which can be done in only a few minutes. It is a bit clunky and its main design flaw is that it's tough to look through the finder scope without bashing your ear on the side of the telescope. A child with a small head might be fine, but adults need to watch out.

Mobility is also an issue. Vertical movement is easy and the focus is smooth, but horizontal movement requires rotating the whole unit, which sacrifices subtlety when stargazing.

It does have its flaws, but for the price, it's a decent starter model and it's small enough to be portable. The images it gives you are clear, so if you want a starter telescope without breaking the bank, this is a solid option.

Verdict: ✪✪✪✪✪

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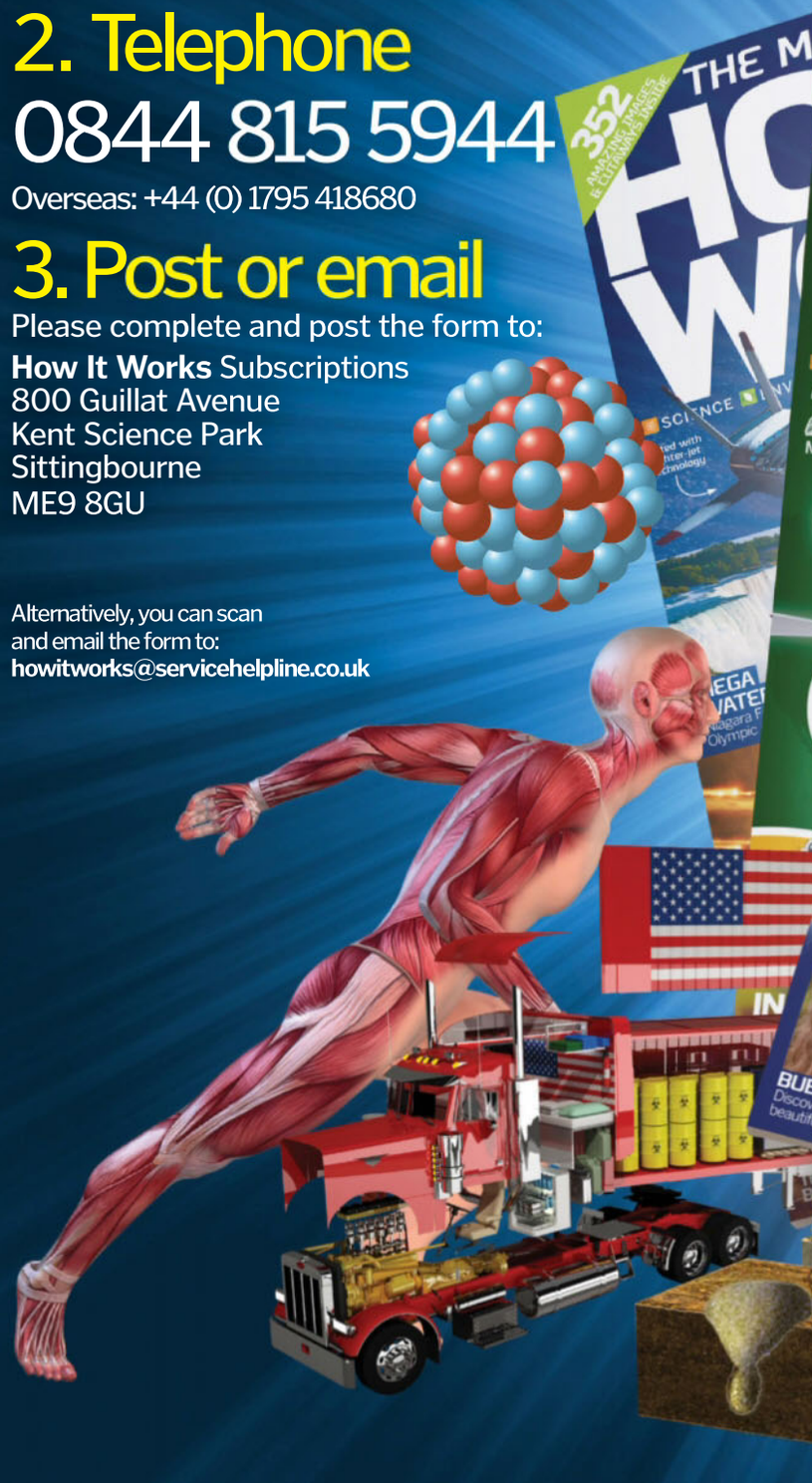

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Make a density tower

Understand the physical properties of liquids with this home experiment

1 Measure your ingredients

For this experiment you'll need a tall, straight-sided glass and a number of ingredients. You don't need all of them, but the more the better! Measure out equal quantities of: Honey, syrup, milk, washing-up liquid, water, vegetable oil and rubbing alcohol or nail varnish remover. Work out the volume of the glass, divide that number by the number of items you have and that will tell you how much of each liquid you will need.

2 Pour the first

Pour the first item that you have got from the above list (in that order) into the glass. It is very important that it doesn't touch the sides. Honey is first on the list because it is the densest of all the liquids. This means its molecules are packed together more tightly than the others, making it hard for other things to pass through it. Density is mass divided by volume, so if volume stays the same but mass increases, density increases.

3 Pour the rest

Following the order of the list, pour in each of the liquids one by one as slowly as possible, trying not to get any down the sides. The items are in that order because they are going from the most dense to the least dense. This will allow each liquid to sit on top of the previous liquid, because less dense things like to be above more dense things. It doesn't matter if the liquids are a little bit mixed up at this stage.

4 Let it settle

If the liquids have merged a little, then give the mixture a couple of minutes in which to separate. This allows each liquid to settle into a different layer, as some drops may have sunk into the liquid below due to the force of its downward momentum as it was poured in. Make a list of the order in which the liquids are in the glass so you know which is which and can tell how dense they are relative to one another.

5 Does it sink?

To further the experiment, select solid objects of varying weights to see how dense they are. A metal bolt, a popcorn kernel, a cherry tomato, a bottle cap and a table tennis ball are good examples of varying items with different densities. Drop them, one by one, into the mixture and see how far down they go. This will demonstrate how dense each item is and will show that even items that seem heavier than any liquid can actually float.

In summary...

Make sure that each item is poured into the glass into the correct order, as a lighter liquid will work its way up through the other liquids and spoil the effect. Pour each item as slowly and carefully as possible and you'll end up having a genuinely cool-looking – not to mention scientifically interesting – table decoration.

NEXT ISSUE
- Osmosis with potato slices
- Grow beans on cotton wool

Sink the perfect hoop

How to impress your mates and drop those all-important three-pointers

1 Prepare your stance

Stand at the three-point line with the ball in your hands. Try not to have the palm of your shooting hand on the ball as the action is in the fingers and wrist. Stand with your feet shoulder-width apart with the foot on the side of your dominant hand slightly further forward. Place your non-dominant hand on the side of the ball to provide stability for the shot. Use just your fingers rather than your whole hand. Your torso should point straight toward the basket.

2 Target and elbow

Focus on where you are hoping to land the ball. This would often be a point on the backboard just above the rim of the basket from your eye line. Focus on that spot rather than the ball or your hand. This will help guide the ball toward your target. Your dominant arm should be cocked at a 90-degree angle and your upper arm raised so the ball is over your head, and your whole body, arm and head are in alignment toward the basket.

3 The shot

Bend your knees and push upward, which will give you more power and elevation. Straighten your elbow, keeping it directly in line with the basket. Flick your wrist forward to give the ball more acceleration and backspin, which will help it to drop downward after hitting the backboard. You should aim for a high-arcing shot as that will help it drop into the basket, as a flatter shot could see ball bouncing further off the backboard and away from the basket.

In summary...

The key to this shot is getting everything in alignment. If your torso, arm and head are all lined up and you are looking at the correct spot, your muscles and eyes should combine to send the ball where you want. After that, it's all a matter of timing, power and a lot of practice.

QUICK QUIZ

Test your mind with ten questions based on this month's content to win an Airfix model of a De Havilland DH.88 Comet aeroplane.

Answer the questions below and then enter online at **www.howitworksdaily.com**

1. What compound is dry ice made from?
2. What do you call a substance that loves and is attracted to water?
3. What does crushed carbon turn into before it becomes a diamond?
4. Which part of your eye is reshaped in orthokeratology?
5. In kilometres, how long is the monarch butterfly's migration?
6. Which national park is host to more geysers than anywhere else?
7. In metres, how tall can a giraffe grow?
8. Which legendary artist and scientist invented the ornithopter?
9. Who patented the motorised vacuum cleaner?
10. In which year was Zulu chieftain Shaka Zulu born?

ISSUE 63 ANSWERS

1. Dr Amy Farrah Fowler **2.** (Complete) Heterochromia **3.** 50 **4.** 1920 **5.** 1897 **6.** *Angry Birds* **7.** Russian **8.** 1976 **9.** Christiaan Huygens **10.** 240km/h

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Letter of the Month

On a cellular level

Dear **HIW**,

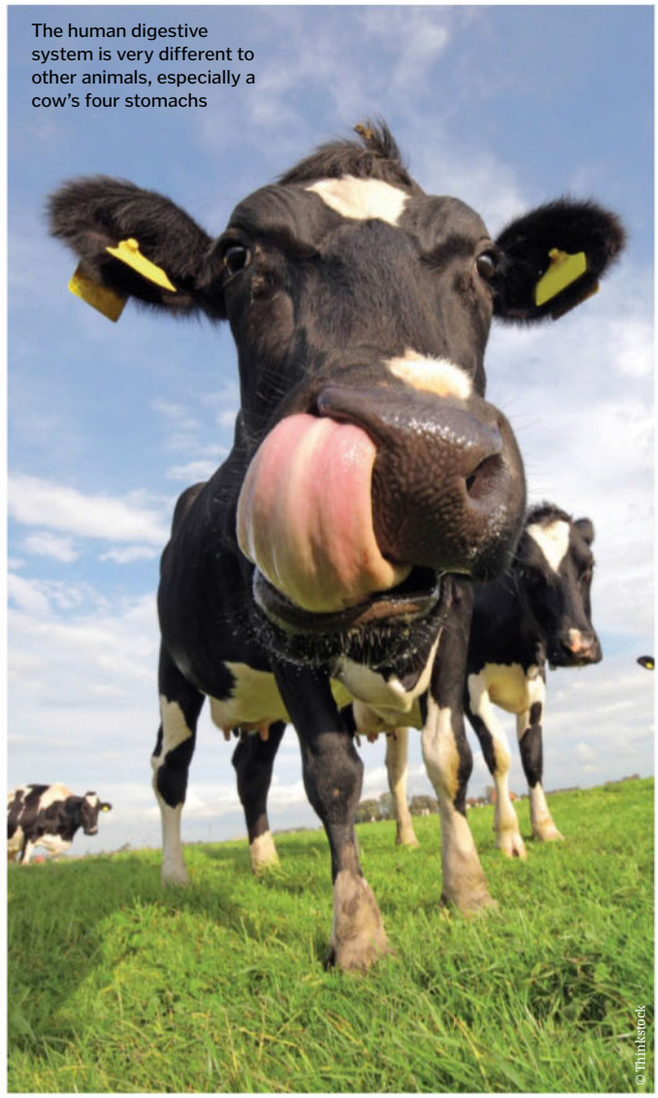
Thank you for this wonderful magazine! I have only read one copy, but I love it so much.

When I studied the digestive system of ruminants and rodents in biology, my teacher said that these animals are host to so-called microorganisms, which secrete cellulase to hydrolyse cellulose, but she was not able to explain how these microorganisms get into these animals' digestive system. I know our digestive system also has some microorganisms (both good and bad for us), but do you know why don't we have these cellulase-secreting microorganisms that ruminants and rodents have?

To add to this question, how does the human body (and also other animals) know which microorganisms are good, so that they will not eliminate these useful little friends?

Sincerely,

Loo Rong Jie



The human digestive system is very different to other animals, especially a cow's four stomachs

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We got in touch with Dr Andrew Preston at the Department of Biology and Biochemistry at the University of Bath, who went into more detail:

"The microbial cells in the human body, referred to as the human microbiome, greatly outnumber human cells. We have co-evolved with it and its now clear that it plays a very important role in health and disease. Our microbiome is picked up from our environment, starting at birth, and it develops over several years into a relatively stable population. Microbiomes are largely host-specific so a ruminant will have a very different community of microbes compared to humans. In the gut, diet is a strong determinant of which microbes are present, as different types of food will support different types of bacteria.

How our bodies distinguish between beneficial (or at least harmless) bacteria of the microbiome and potentially harmful microbes such as disease causing bacteria is also of great interest but not fully understood but it is clear that our immune systems do interact with many of these bacteria but react differently to our normal resident bacteria compared to potential pathogens."

Sadly, there's still no way to make a proper lightsaber... yet

Light-speed query

Dear **HIW**,

I'm a new reader, now on my second issue. Before asking my question I want to say that I've read the light-speed article and I think time does not slow down for the man on the train, it is the speed of light that slows down as the train moves close to the light speed. So I would say this is just optical illusion. And my question is about *Star Wars*. Is it possible to make a lightsaber? Because I think laser light would go on forever.

Looking forward to your reply.

Davronbek Muratov

There have been many different theories to the speed of light throughout history and the current and most respected view is still Albert Einstein's theory of relativity. This states that the speed of light is a constant speed of 299,792.458 kilometers (186,282.397 miles) per second. So we have to say that the speed of light doesn't slow down, it is in fact the man and the train contracting as time seems to pass more slowly. Keep having a look at science books and online, though, as theories are forever being debated!

As for a lightsaber, like you say it's pretty much impossible to harness light in a 'blade' and two 'sabers' would just pass through each other rather than collide. A possible alternative would be a 'plasma-saber' but this power would not be able to be contained in a small lightsaber handle.

"There have been many different theories on the speed of light throughout history"

Tackling the fire triangle

Dear HIW,
Many aircraft accidents as we know are down to fire, such as in the case of exposed wiring, or dangerous cargo like lithium-ion batteries. However, could fires in the cargo hold of an aircraft be prevented by removing all the oxygen from the bay? As without oxygen, a fire cannot take place, unless there was another source of oxygen, such as oxidisers incorporated into explosives. Even though many jet aircraft fly at high altitudes, where there is little oxygen (this is if the hold were not sealed), fire is still an ever-present danger.

Would creating a vacuum in a sealed hold prevent explosions caused by fire? Would a vacuum cause stress to the fuselage, or hinder the state of cargo on board? If it were possible, would it be financially viable, or too time consuming? Your magazine is a great read.
Andy

That is an interesting and original idea! With no oxygen, a fire couldn't erupt, as the fire triangle would not be complete. But a vacuum could create more problems than it solves. Having no oxygen in the hold would change the weight of the plane so different aerodynamic measures would have to be put in place. This method could also damage some of the luggage, so trial and error would be needed to see how different products react to a vacuum. And it would indeed be time consuming and expensive to create the conditions for every single flight.

Will aircraft be safer with no oxygen in the cargo hold?

Darkest before the dawn

Dear HIW,
I have a question about the darkest time of the night.

I understand that the darkest time of the night is just before the sunrise. I know the darkness of the night depends on how far the Sun and the Moon are below the horizon. But I don't understand why exactly before the dawn?
I hope you can help.
Daniz Aryani

There are lots of conditions required to make the night sky darker or lighter. Obviously, the further you live from a city the less light pollution there will be, but nights can also be at their gloomiest when there is a new moon and no cloud cover. In regard to time, the darkest part of the night is whenever the Sun has fully set. The changing of the seasons alters this time with the different amount of light hours throughout the year.

What's happening on... Twitter?

We love to hear from **How It Works**' dedicated followers. Here we pick a few tweets that caught our eye this month...

@missmayim
Thanks **@HowItWorksmag** for the nice article. i love being in NON entertainment magazines almost more than entertainment ones.

Laughing Jack
@thegoverner1978
@HowItWorksmag your magazine is helping a generation of people avoid looking stupid in front of our kids. Make it interesting and they learn

Matt
@MattmanM
@HowItWorksmag class ! #WinItWednesday #intrigued !!

Juliet Eliza Gilles
@juliethoneybee1
@HowItWorksmag fantastic prize to win :)

Sammie Phillips
@SammiePhillips1
@HowItWorksmag Wow Fab Giveaway! Thanks for the chance to win :D #Competition xx

shona mackie
@shonamackie
@HowItWorksmag Quiz all completed was great to do kids helped mum and helped them with history Expand

SATA USA
@SATA_DanAm
Not suggesting anything, **@howitworksmag**, but we're ready for our turn whenever you are. #Wereavailable http://www.danamair.com/how-it-works/

Scott Malthouse
@scottmalt
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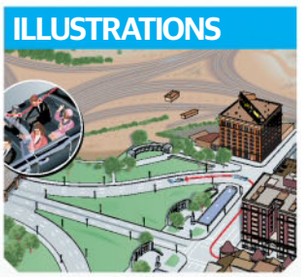

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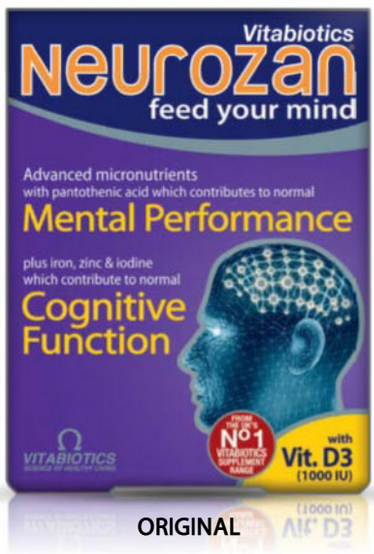

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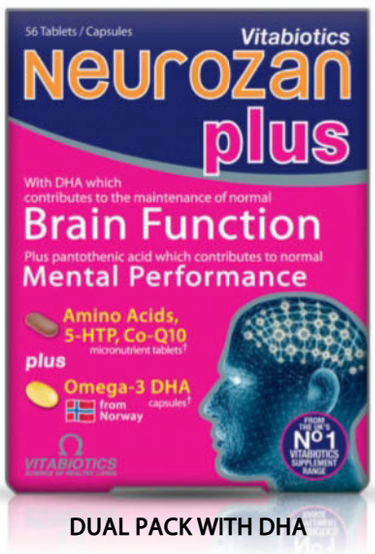

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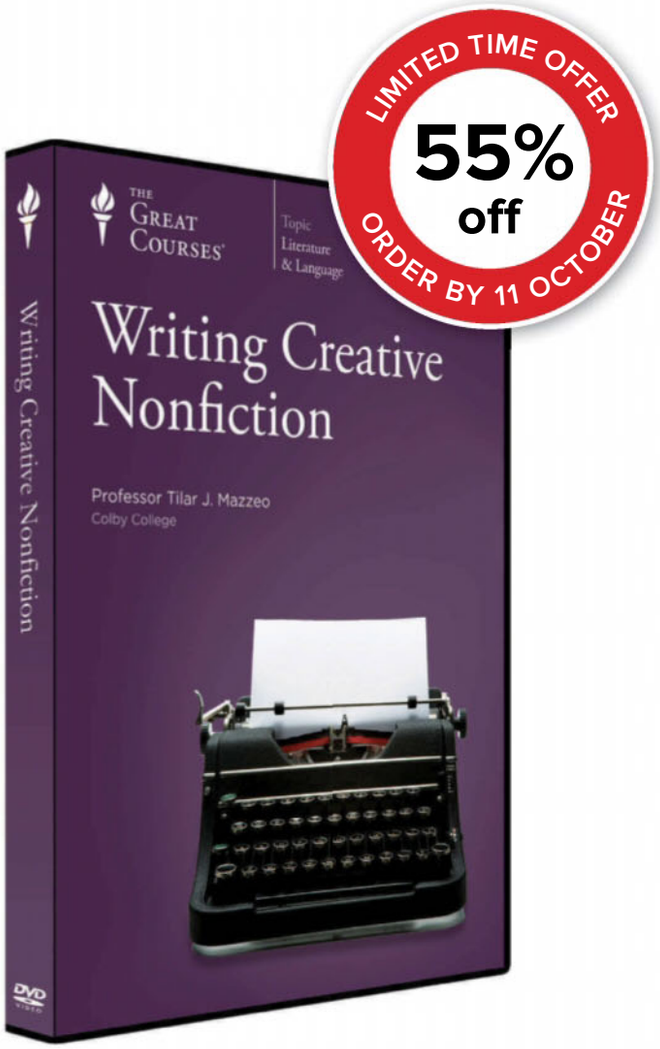

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